CAMBRIDGE UNIVERSITY PRESS
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LONDON: FETTER LANE, E.C. 4

H. K. LEWIS & CO., LTD., 136, GOWER STREET, LONDON, W.C. 1
WHELDON & WESLEY, LTD., 2–4, ARTHUR ST., NEW OXFORD ST., LONDON, W.C. 2
CHICAGO: THE UNIVERSITY OF CHICAGO PRESS
(AGENT FOR THE UNITED STATES AND CANADA)
BOMBAY, CALCUTTA, MADRAS: MACMILLAN & CO., LTD.
TOKYO: THE MARUZEN-KABUSHIKI-KAISHA

The British Mycological Society

(Recognosce notum, ignotum inspice)

TRANSACTIONS

Volume VIII

Edited by
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CAMBRIDGE
AT THE UNIVERSITY PRESS
1923

PRINTED IN GREAT BRITAIN

THE WORCESTER FORAY.

September 19th to September 24th, 1921.

The twenty-fifth annual meeting and autumn foray took place at Worcester, at the invitation of the Worcestershire Naturalists' Club, from September 19th to 24th, 1921.

A few members of the party assembled during the previous week-end, and on the Sunday Mr Carleton Rea arranged a short expedition in the Malvern district. The party travelled to Malvern Link by motor-bus, and then walked down the Cowleigh Road to Cowleigh Wood. Subsequently a visit was made to Croft Wood, which is just over the border in Herefordshire. The return journey was made through Great Malvern. This expedition provided quite a number of species with which to start the week's work.

As usual the majority of the members assembled on the Monday evening and were welcomed on their visit to Worcestershire by the Vice-President (Mr F. T. Spackman, F.G.S.) and members of the Worcestershire Naturalists' Club at a conversazione in the Art Gallery at the Victoria Institute, Worcester. In the morning of Tuesday, September 20th, a council meeting was held, and this was followed in the evening of the same day by the annual general meeting.

Mr F. T. Brooks, M.A., was elected President for 1922, and Dr E. J. Butler was chosen to fill the vacancy thus caused in the Council.

In place of the two members retiring according to rule, Professor O. V. Darbishire and Mr C. H. Grinling were elected members of the Council. The other officers were re-elected.

It was decided to hold the autumn foray in 1922 at Keswick, and to arrange the period to include a week-end, if possible that of September 16th–17th.

Mr W. N. Cheesman was appointed delegate of the Society to the British Association meeting at Hull.

The whole of Tuesday was taken up by an expedition to Wyre Forest. The party took train to Cleobury Mortimer, and after a short walk along the road entered Weston Firs and Weston Plantation. After lunch Coachroad Coppice and the open ground adjoining Furnace Mill were visited, and then the path along Dowles Brook was followed as far as Wyre Forest Station, whence the return journey was made. Owing to the exceptionally dry summer the forest was not as rich in fungi

as usual, and considerable hunting had to be done. Old charcoal heaps yielded a few charcoal-loving species, as *Polystictus perennis*, *Humaria carbonigena*, *Pyronema confluens*, and *Collybia ambusta*. Some stacks of birch logs near Dowles Brook were rich in micro-fungi. A noteworthy find here was *Hymenochaete tabacina*, which appears to be much more rare in this country than *H. rubiginosa* and *H. corrugata*. *Russula chloroides* was abundant, and *Nyctalis parasitica* was found everywhere on decaying *R. nigricans*. Mr W. B. Allen brought a number of rare and interesting species from Horderley and Benthall, Shropshire.

On Wednesday Ockeridge Wood and Monk Wood were visited. The former proved most productive, very few additions to the list being made in Monk Wood which was more dry. Some fine specimens of *Pholiota squarrosa* were secured at the base of an *Abies*, which is an unusual habitat for this species. The best finds of the day were *Hygrophorus Wynniae* and *Otidea leporina*, the latter gathered by Miss M. Brett. In the evening Mr Carleton Rea delivered his Presidential Address.

On Thursday a visit was paid to Shrawley Wood and was remarkable for the large number of specimens of the somewhat rare *Strobilomyces strobilaceus*. A characteristic tree here was the small-leaved Lime (*Tilia cordata*), and a number of resupinates, including *Tulasnella incarnata*, were recorded on this host. Some fine tufts of *Polyporus intybaceus* were found growing at the roots of Sweet Chestnut (*Castanea vesca*). This day's foray proved the most interesting of all, this wood being damper than others visited. *Clitocybe cinerascens* (Bull.) Quél., *Craterellus cornucopioides*, *Cortinarius triumphans*, *C. cyanopus*, *Lactarius lilacinus*, *Polyporus rutilans*, *P. mollis* and *Corticium atrovirens* were among the more noteworthy finds. The owner (Mrs J. H. Allan) very kindly entertained the Council to a welcome cup of tea and the President reported that on a preliminary visit to this wood in company with their foray secretary, Mr A. A. Pearson, he had found *Arachnopeziza nivea* Lort, a discomycete new to the British fungus flora.

In the evening Professor A. H. R. Buller gave a short paper, illustrated by lantern-slides, on "Snails in relation to Fungi," and Dr Butler initiated a discussion on "The Amateur in relation to Mycology."

An expedition to the Trench Woods was made on Friday. These were very dry, and very few of the larger fungi were found, but notwithstanding this Miss C. A. Cooper detected specimens of *Astrosporina duriuscula*; *Mycena dilatata* and *Androsaceus epiphylloides*, and some interesting micro-forms also occurred. In one spot a large patch of *Corticium fasti-*

diosum was found on the bare clayey soil. *Sebacina incrustans* and *Thelephora anthocephala* occurred in similar situations. In a grassy drive leaves of *Spiraea Ulmaria* yielded numerous specimens of a small spider attacked by *Isaria arachnophila.* Of the larger forms the most outstanding find was a magnificent specimen of *Polyporus rufescens*, brought in by Mr S. P. Wiltshire.

In the evening Mr J. Ramsbottom gave a paper on "The origin of saprophytism in Phanerogams."

The meeting concluded with cordial votes of thanks to the Worcester Museum and Library Committee for the use of the Victoria Institute and Library, to the Education Committee for the use of the lecture theatre and to the various owners and tenants who had given permission for visits to their estates. Votes of thanks were also passed to the President, to the Foray Secretary, Mr Pearson, and to Miss Wakefield.

For assistance in compiling the following list of species found I am especially indebted to Mr Carleton Rea, Mr J. Ramsbottom and Dr J. S. Bayliss Elliott. The latter is responsible for many records of Discomycetes.

Wo. = Neighbourhood of Worcester. *W.* = Wyre Forest. *O.* = Ockeridge Wood and Monk Wood. *S.* = Shrawley Wood. *T.* = Trench Woods. *C.* = Cowleigh Wood. *Cr.* = Croft Wood.

HYMENOMYCETES.

Amanita phalloides (Vaill.) Fr. *W.S.*, mappa (Batsch) Fr. *W.S.*, muscaria (L.) Fr. *W.S.*, rubescens Fr. *S.*, nitida Fr. *S.*

Amanitopsis vaginata (Bull.) Roze *W.S.*, strangulata Fr. *C.*

Armillaria mellea (Vahl.) Fr.

Lepiota procera (Scop.) Fr. *W.*, rachodes (Vitt.) Fr. *S.*, gracilenta (Krombh.) Fr. *W.*, acutesquamosa (Weinm.) Fr., amianthina (Scop.) Fr. *O.*, Bucknallii B. and Br.

Tricholoma sejunctum (Sow.) Fr. *O.*, resplendens Fr. *C.*, spermaticum Fr. *S.*, flavobrunneum Fr. *O.*, rutilans (Schaeff.) Fr. *W.O.*, chrysites (Jungh.) Gill. *C.*, saponaceum Fr. *S.T.*, sulphureum (Bull.) Fr. *S.*, nudum (Bull.) Fr. *S.*, melaleucum (Pers.) Fr. *W.*, var. polioleucum Fr. *W.*

Clitocybe clavipes (Pers.) Fr. *W.*, phyllophila Fr. *W.*, aggregata (Schaeff.) Fr. *S.*, infundibuliformis (Schaeff.) Fr. *C.*, inversus (Scop.) Fr. *W.*, metachroa, Fr. *O.*, fragrans (Sow.) Fr. *S.*, cinerascens (Bull.) Quél. *S.*

Laccaria laccata (Scop.) B. and Br. *C.S.O.*, var. amethystina (Vaill.) B. and Br. *C.*

Collybia radicata (Relh.) Berk. *W.*, platyphylla Fr. *W.*, fusipes (Bull.) Berk. *C.S.*, distorta Fr. *O.*, butyracea (Bull.) Fr. *S.*, velutipes Fr. *W.O.*, dryophila (Bull.) Fr. *C.T.*, aquosa (Bull.) Fr. *C.*, ambusta Fr. *W.*

Mycena pura (Pers.) Fr. *S.*, rugosa Fr. *C.*, galericulata (Scop.) Fr. *O.T.*, polygramma (Bull.) Fr. *C.O.T.*, inclinata Fr. *O.*, amicta Fr. *W.*, sanguinolenta (A. and S.) Fr. *O.*, galopus (Pers.) Fr. *W.S.*, var. nigra Fl. Dan. *W.S.T.*, epipterygia (Scop.) Fr. *O.*, dilatata Fr. *T.*, tenerrima Berk. *O.*

Omphalia fibula (Bull.) Fr. *C.*, var. Swartzii Fr. *C.*, integrella (Pers.) Fr. *W.*

Pleurotus ulmarius (Bull.) Fr., subpalmatus Fr. *Wo.*, acerosus Fr. *W.*, applicatus (Batsch) Berk. *T.*

Hygrophorus eburneus (Bull.) Fr. *W.*, conicus Fr. *S.*, Wynniae B. and Br. *O.*

Lactarius scrobiculatus (Scop.) Fr., torminosus (Schaeff.) Fr. *W.*, turpis (Weinm.) Fr. *S.*, pubescens Fr. *C.*, insulsus Fr. *C.*, blennius Fr. *S.*, uvidus Fr. *T.*, pyrogalus (Bull.) Fr. *W.O.T.*, chrysorheus Fr. *W.S.*, vellereus Fr. *O.T.*, deliciosus (L.) Fr. *W.*, quietus Fr., rufus (Scop.) Fr. *O.*, glyciosmus

Fr. *S.*, fuliginosus Fr. *S.T.*, lilacinus (Lasch) Fr. *S.*, serifluus (DC.) Fr. *S.*, mitissimus Fr. *O.S.*, subdulcis (Pers.) Fr. *Cr.W.S.*

Russula nigricans (Bull.) Fr., adusta (Pers.) Fr. *S.T.*, chloroides (Krombh.) Bres. *C.W.S.T.*, furcata (Pers.) Fr. *C.*, caerulea (Pers.) Fr. *W.O.*, atropurpurea (Krombh.) Maire *W.O.S.*, rubra (Krombh.) Bres. *O.*, drimeia Cooke, *O.*, virescens (Schaeff.) Fr. *O.*, lepida Fr. *C.S.T.*, xerampelina (Schaeff.) Fr. *Cr.W.O.S.*, vesca Fr. *O.*, cyanoxantha (Schaeff.) Fr. *C.W.*, consobrina Fr. *S.*, var. sororia Fr. *O.*, foetens (Pers.) Fr. *Cr.O.W.S.T.*, emetica (Schaeff.) Fr. *W.*, ochroleuca (Pers.) Fr. *C.W.S.T.*, fragilis Fr. *C.S.T.*, nitida (Pers.) Fr. *S.*, punctata (Gill.) Maire *C.T.*, armeniaca Cke. *S.*, lutea (Huds.) Fr. *S.*

Cantharellus cibarius Fr. *W.T.*, aurantiacus (Wulf.) Fr. *C.W.*

Nyctalis parasitica (Bull.) Fr., asterophora Fr. *S.*

Marasmius oreades (Bolt.) Fr. *C.*, ramealis (Bull.) Fr. *O.T.*, rotula (Scop.) Fr. *W.*

Androsaceus epiphylloides Rea *T.*

Lentinus cochleatus (Pers.) Fr. *W.Wo.*

Panus stypticus (Bull.) Fr. *W.*

Schizophyllum commune Fr. *S.*

Pluteus cervinus (Schaeff.) Fr. *W.O.S.*, salicinus (Pers.) Fr. *S.*, nanus (Pers.) Fr. *O.T.*

Clitopilus prunulus (Scop.) Fr. *W.S.*

Claudopus variabilis (Pers.) W. G. Sm. *O.*

Pholiota aegerita (Porta) Fr. *Wo.*, squarrosa (Mull.) Fr. *O.* (at base of *Abies*), marginata (Batsch) Fr. *O.S.*, mutabilis (Schaeff.) Fr. *W.S.*

Inocybe cincinnata Fr. *T.*, pyriodora (Pers.) Fr. *S.*, rimosa (Bull.) Fr. *S.*, duriuscula Rea *T.*, asterospora Quél., geophylla (Sow.) Fr. *Cr.W.T.*, var. violacea Pat. *S.*

Hebeloma fastibile Fr. *W.O.*, glutinosum (Lindg.) Fr. *S.*, mesophaeum Fr. *W.O.*, crustuliniforme (Bull.) Fr. *C.*

Flammula carbonaria Fr. *W.*, ochrochlora Fr. *O.*, sapinea Fr. *O.S.*

Naucoria melinoides (Bull.) Fr. *W.O.*, escharoides Fr. *O.S.*

Pluteolus aleuriatus Fr. *C.O.*

Galera hypnorum (Schrank) Fr. *W.*

Tubaria furfuracea (Pers.) W. G. Sm. *W.*, inquilina Fr. *C.*

Crepidotus mollis (Schaeff.) Fr. *O.*

Cortinarius (Phlegmacium) triumphans Fr. *S.*, varius (Schaeff.) Fr. *C.*, cyanopus Fr. *S.*, (Myxacium) elatior (Pers.) Fr. *S.*, (Dermocybe) tabularis (Bull.) Fr. *S.*, lepidopus Cke. *S.*, cotoneus Fr., (Telamonia) macropus Fr. *S.*, torvus Fr. *S.*, hinnuleus (Sow.) Fr. *C.W.*, hemitrichus (Pers.) Fr. *S.*, (Hydrocybe) leucopus (Bull.) Fr. *S.*, decipiens (Pers.) Fr. *S*

Paxillus involutus (Batsch) Fr. *C.W.*

Psaliota purpurascens Cke. *S.*, campestris (Linn.) Fr. *C.*, silvatica (Schaeff.) Fr. *S.*, haemorrhoidarius Kalchbr. *W.*

Stropharia aeruginosa (Curt.) Fr. *O.S.*, semiglobata (Batsch) Fr. *Cr.*

Hypholoma sublateritium (Schaeff.) Fr. *O.T.*, fasciculare (Huds.) Fr., epixanthum (Paul.) Fr. *C.W.*, pyrotrichum (Holmsk.) Fr. *W.*, velutinum (Pers.) Fr. *W.O.*, appendiculatum (Bull.) Fr. *W.O.*, hydrophilum (Bull.) Fr. *W.O.S.*

Psathyra corrugis (Pers.) Fr. *O.S.T.*

Bolbitius titubans (Bull.) Fr. *C.*

Coprinus atramentarius (Bull.) Fr. *W.O.*, sterquilinus Fr. *S.*, cinereus (Schaeff.) Fr. *Cr.O.*, niveus (Pers.) Fr. *Cr.*, micaceus (Bull.) Fr. *W.S.*, domesticus (Pers.) Fr. *W.O.*, plicatilis (Curt.) Fr. *W.O.*

Panaeolus sphinctrinus Fr. *C.W.*, campanulatus (Linn.) Fr. *C.*, papilionaceus (Bull.) Fr. *S.*

Anellaria separata (Linn.) Karst. *C.*

Psathyrella gracilis (Pers.) Fr. *C.*, disseminata (Pers.) Fr. *O.S.*

Gomphidius viscidus (Linn.) Fr. *W.*, maculatus (Scop.) Fr. *O.*, gracilis Berk. *O.*

Boletus luteus (Linn.) Fr. *W.*, elegans (Schum.) Fr. *W.O.*, granulatus (Linn.) Fr. *W.*, badius Fr. *W.S.*, piperatus (Bull.) Fr. *W.*, chrysenteron (Bull.) Fr. *W.S.*, versicolor Rost. *S.*, edulis (Bull.) Fr. *C.*, laricinus Berk. *Cr.O.*,

versipellis Fr. *C.W.*, scaber (Bull.) Fr. *W.S.T.*, felleus (Bull.) Fr. *S.*, appendiculatus (Schaeff.) Fr. *S.*

Strobilomyces strobilaceus (Scop.) Berk. *S.*

Fistulina hepatica (Huds.) Fr. *W.O.*

Polyporus squamosus (Huds.) Fr. *S.*, rufescens (Pers.) Fr. *T.*, Schweinitzii Fr. *T.*, varius Fr. *O.*, elegans (Bull.) Fr., var. nummularius Fr. *T.*, intybaceus Fr. *S.* (on *Castanea vesca*), giganteus (Pers.) Fr. *S.*, dryadeus Fr. *Wo.S.*, hispidus Fr. *Wo.*, mollis Fr. *S.*, rutilans (Pers.) Fr. *S.*, betulinus (Bull.) Fr., adustus (Willd.) Fr. *W.*, fragilis Fr. *W.S.*

Fomes connatus Fr. *W.*, annosus Fr. *W.O.S.*, igniarius Fr. *W.*, pomaceus (Pers.) Fr. *Wo.*, ferruginosus (Fr.) Mass. *W.*

Ganoderma lucidum (Leyss.) Karst. *T.*

Polystictus perennis (Linn.) Fr. *W.*, versicolor (Linn.) Fr. *C.W.*, radiatus (Sw. Fr. *W.*, hirsutus (Schrad.) Fr. *O.S.*, Wynniae (Berk.) Cooke, *O.*

Poria eupora Karst. *T.*, sanguinolenta Fr. *O.*

Daedalea quercina (Linn.) Fr. *C.O.*, confragosa (Bolt.) Fr. *O.*

Merulius tremellosus (Schrad.) Fr. *W.S.*, corium Fr. *S.*

Hydnum repandum (Linn.) Fr. *W.O.T.*, var. rufescens (Pers.) Fr. *S.*, udum Fr. *W.S.T.*

Irpex obliquus (Schrad.) Fr. *W.O.T.*

Phlebia merismoides Fr. *T.*, radiata (Sow.) Fr. *W.O.*

Odontia fimbriata (Pers.) Fr. *W.O.*, farinacea (Pers.) Quél. *O.T.*

Grandinia granulosa Fr. *T.*

Craterellus cornucopioides (Linn.) Fr. *S.*

Thelephora anthocephala Fr. *Cr.O.T.*

Stereum hirsutum (Willd.) Fr. *W.*, purpureum (Pers.) Fr. *C.Wo.*, rugosum (Pers.) Fr. *Cr.T.*, sanguinolentum (A. and S.) Fr. *W.*, spadiceum Fr. *T.*

Hymenochaete tabacina (Pers.) Lév. *W.*

Corticium arachnoideum B. and Br. *S.T.*, botryosum Bres. *W.T.*, confine Bourd. and Galz. *T.*, fastidiosum (Pers.) Bres. *T.*, echinosporum Ell. *W.*, caeruleum (Schrad.) Fr. *O.*, atrovirens Fr. *S.*, Pearsonii Bourd., porosum B. and Br. *W.T.*, polygonium (Pers.) Fr. *S.* (on *Tilia*).

Peniophora Aegerita v. H. and Lit. *O.*, glebulosa Bres. *O.T.*, subalutacea (Karst.) v. H. and L., longispora (Pat.) v. H. and L. *T.*, sanguinea (Fr.) Bres. *O.T.*, cremea Bres. *W.*, setigera (Fr.) Bres. *T.*, aurantiaca Bres. *O.S.T.*, cinerea (Fr.) Cke. *O.S.T.*, quercina (Pers.) Cke. *Cr.W.T.*, hydnoides C. and M. *W.O.T.*

Hypochnus fuscus (Pers.) Karst. *W.T.*, ferrugineus (Pers.) Fr. *T.*

Coniophora puteana (Schum.) Fr. *W.*

Solenia anomala (Pers.) Fr.

Clavaria cinerea (Bull.) Fr. *W.O.S.*, cristata (Holmsk.) Fr. *W.O.T.*, rugosa (Bull.) Fr. *W.*, inaequalis (Müll.) Fr. *C.S.*

Pistillaria puberula Berk. *O.*

Hirneola Auricula-Judae (Linn.) Fr. *O.S.*

Tremella mesenterica (Retz.) Fr. *T.*

Exidia glandulosa (Bull.) Fr. *S.*

Sebacina incrustans Tul. *Cr.T.*

Dacryomyces deliquescens (Bull.) Duby, *W.S.T.*

Femsjonia luteo-alba Fr. *W.*

Calocera cornea (Batsch) Fr. *W.O.S.*, stricta Fr. *W.*, viscosa (Pers.) Fr. *W.*

Tulasnella incarnata Juel *S.T.*

Phallus impudicus (Linn.) Pers. *S.*

Mutinus caninus (Huds.) Fr. *O.*

Cyathus striatus Hoffm. *O.*

Crucibulum vulgare Tul. *S.*

Lycoperdon perlatum Pers. *W.S.*, depressum Bon. *S.*, pyriforme (Schaeff.) Pers. *W.*

Scleroderma verrucosum (Bull.) Pers. *O.W.*

UREDINEAE.

Puccinia Violae (Schum.) DC. *O.*, pulverulenta Grev. *W.*, obtegens (Link) Tul. *C.Wo.*, Hieracii (Schum.) Mart. on *Hieracium boreale*, *T.*, Glechomatis DC.

O., Menthae Pers. *T.*, Caricis (Schum.) Rebent. on *Carex pendula*, *O.*, obscura Schroet. *C.O.S.*, Pruni-spinosae Pers. *S.*, secalina Grove *Wo.*
Triphragmium Ulmariae (Schum.) Link *T.*
Phragmidium violaceum (Schultz) Wint. *S.O.T.*
Kuehneola albida (Kuehn.) Magn. *W.O.T.*
Coleosporium Senecionis (Pers.) Fr. *S.*, Tussilaginis (Pers.) Kleb. *S.*
Pucciniastrum Circaeae (Schum.) Schroet. *O.T.*
Melampsora Euphorbiae Cast. *Wo.*
Melampsoridium betulinum (Pers.) Kleb. *W.*

USTILAGINEAE.

Sphacelotheca Hydropiperis (Schum.) de By. *O.*
Ustilago Scabiosae (Sow.) Wint.
Urocystis Violae (Sow.) Fisch. *S.*

PYRENOMYCETES.

Sphaerotheca pannosa (Wallr.) Lév. *Cr.*, Castagnei Lév. *S.T.*
Podosphaera oxyacantha (DC.) de By. *C.*
Uncinula Aceris (DC.) Sacc. *T.*
Phyllactinia suffulta (Rebent.) Sacc. *O.*
Erysiphe Cichoracearum DC. *S.*, graminis DC. *Wo.O.S.*, Galeopsidis DC. on *Lamium purpureum*, *S.*, tortilis (Wallr.) Fr. *T.*, Polygoni DC. *C.W.S.*
Nectria episphaeria (Tode) Fr. *W.*, coccinea (Pers.) Fr. *W.O.*, cinnabarina (Tode) Fr. *O.*
Hypomyces aurantius (Pers.) Tul. *O.*, rosellus (A. and S.) Tul. *S*
Hypocrea citrina Fr. *W.*, gelatinosa Fr. *O.*
Epichloe typhina (Pers.) Tul. *T.*
Cordyceps militaris (Linn.) Link *W.O.S.*
Leptospora ovina (Pers.) Fuck. *S.*
Lasiosphaeria hirsuta Ces. and de Not. *S.*
Rosellinia aquila (Fr.) de Not. *O.*
Sphaerella Fragariae Sacc. *S.*
Venturia inaequalis (Cooke) Aderh. on *Pyrus torminalis*, *T.*
Diaporthe leiphaemia Sacc. *T.*
Diatrypella quercina (Pers.) Nits. *O.S.*
Diatrype Stigma (Hoffm.) de Not. *W.*, disciformis (Hoffm.) Fr. *S.*, verrucaeformis Fr. *S.*
Hypoxylon multiforme Fr. *W.O.S.T.*, fuscum Fr. *W.*, coccineum Bull. *W.O.*, rubiginosum Fr. *W.*, serpens Fr. *T.*
Xylaria Hypoxylon (Linn.) Grev. *W.O.T.*
Phyllachora graminis (Pers.) Fuck. *O.*, Junci (Fr.) Fuck. *O.*

HYSTERIACEAE.

Rhopographus Pteridis (Sow.) Wint. *O.*
Hypoderma virgultorum DC. *S.*
Dichaena quercina Fr. *O.T.C.*

DISCOMYCETES.

Helvella crispa (Scop.) Fr. *W.*
Galactinia badia (Pers.) Boud. *T.*, succosa (Berk.) Sacc. *S.*
Peziza aurantia Pers. *W.*
Otidea leporina (Batsch) Fuck. *O.S.*
Aleuria sepiatra (Cooke) Boud. *W.*
Humaria carbonigena (Berk.) Sacc. *W.*
Lachnea hemisphaerica (Wigg.) Gill. *W.O.*
Cheilymenia rubra (Cke.) Boud. *W.*
Coprobia granulata (Bull.) Boud. *S.O.*
Ascobolus furfuraceus Pers. *S.W.*, vinosus Berk. *S.*
Cudoniella acicularis (Bull.) Schroet. *O.T.*
Calycella claroflava (Grev.) Boud. *S.*
Cornye sarcoides (Jacq.) Tul. *W.*

Orbilia xanthostigma Fr. *W.O.S.*
Hyalinia inflatula (Karst.) Boud. *W.S.T.*
Sclerotinia Curreyana (Berk.) Karst.—sclerotia only, *O.W.*
Phialea firma Pers. *W.C.*
Chlorosplenium aeruginosum (Oeder.) de Not. *O.T.*
Helotium herbarum (Pers.) Fr. *S.*, virgultorum (Wahl.) Karst. *O.T.*, cyathoideum (Bull.) Karst. *T.*
Dasyscypha virginea (Batsch) Fr. *W.T.*, ciliaris (Schrad.) Sacc. *W.S.T.*
Trichoscypha calycina (Schum.) Boud. *Cr.W.*
Hyaloscypha hyalina (Pers.) Boud. *W.*
Urceolella leuconica (Cooke) Boud. *O.*
Mollisia cinerea (Batsch) Karst. *W.O.S.T.*, Populi Bayliss Elliott *T.*
Pyronema confluens (Pers.) Tul. *W.*
Cenangium Prunastri (Pers.) Fr. *Wo.*
Propolis faginea (Schrad.) Karst. *W.*
Lecanidion proximum (B. and Br.) Sacc. *O.*
Stegia Ilicis Fr. *C.*
Rhytisma acerinum (Pers.) Fr. *W.T.*

PHYCOMYCETES.

Cystopus candidus (Pers.) de By. *S.*
Peronospora effusa (Grev.) Rabh. on *Chenopodium*, *Wo.S.*, parasitica (Pers.) Tul. *S.*, alta Fuck. *S.*
Bremia Lactucae Reg. on *Senecio vulgaris*, *Wo.*
Spinellus fusiger (Link) van Tiegh. *O.*
Syzygites megalocarpus Ehrb. *C.O.*
Thamnidium elegans Link *W.*

SPHAEROPSIDACEAE.

Phyllosticta Violae Desm. *S.*
Phoma conigena Karst. *O.*
Septoria Rubi Westend. *C.W.*, piricola Desm. *S.*, Fragariae Desm. *S.*

MELANCONIACEAE.

Gloeosporium Ribis (Lib.) Mont. and Desm. *S.*
Melanconium betulinum Schn. and Kunze *T.*

LEPTOSTROMACEAE.

Leptostroma juncacearum Sacc. *T.*

HYPHOMYCETES.

Oidium alphitoides Griff. and Maubl. *C.O.*
Monilia fructigena Schum. *Wo.*, cinerea Bon. *Wo.*
Rhinotrichum Thwaitesii B. and Br. *O.T.*
Sepedonium chrysospermum (Bull.) Fr. *C.W.O.S.*
Trichoderma viride (Pers.) Fr. *W.O.*
Botrytis cinerea Pers. *O.Wo.*
Ramularia calcea (Desm.) Ces. *C.*, lactea (Desm.) Sacc. *O.*, Knautiae (Mass.) Bub. *T.*, Primulae Thuem. *Cr.*
Ovularia obliqua (Cooke) Oud. *Cr.O.*
Sporotrichum sulfureum Grev. *T.*
Bispora monilioides Corda *O.*
Stachylidium cyclosporum Grove *W.*
Cercospora Mercurialis Passer. *O.*
Helicosporium viride Corda *S.*
Volutella ciliata Fr. *T.*
Isaria arachnophila Ditm. *S.T.*
Tilachlidium tomentosum (Schrad.) Lind. on *Trichia varia*, *S.*

LIST OF MYCETOZOA FOUND DURING THE WORCESTER FORAY.

From Sept. 19th to 23rd, 1921.

By G. Lister, F.L.S.

After the unusually dry summer, hopes for a good harvest of Mycetozoa were not high; some showers had fallen, however, in Worcestershire in August and September, with the result that every wood we visited produced something of interest. Altogether thirty-eight different species were observed—by no means the smallest number obtained on one of our autumn forays; but on the whole our gleanings were scanty, and several species that are usually abundant were represented by one or two gatherings only. *Diderma testaceum,* found in Shrawley Wood, is a new record for the county.

On Sept. 20th Wyre Forest with its extensive woods of oak, mixed with spruce, sweet-chestnut and poplar, and with undergrowth of bracken and bramble, gave us eighteen species; perhaps the largest development seen of any one species was of *Perichaena corticalis,* quantities of which were found on a pile of small wood on moist ground. Sept. 21st we visited Ockeridge and Monk Woods, consisting of oak, with some spruce, alder and yew, with undergrowth of hazel and bracken; a small plantation of larch arose from a bed of bramble too dense to afford good hunting ground. Large growths of *Cribraria argillacea* were seen on old yew logs, and several colonies of *Stemonitis hyperopta* were obtained on decaying oak, horse-chestnut and other wood; the latter species is distinguished in the field by its reddish lilac tint from the browner sporangia of *Comatricha typhoides,* of which it has until recently been considered a variety. Along a path running through Monk Wood, *Stemonitis fusca* was found maturing on patches of moist clay and dead leaves; the plasmodium had evidently been feeding on a layer of branches laid down as a foundation to the path, and had crept up through the clay to form sporangia. On Sept. 22nd we drove to Shrawley Wood, where groves of oak and lime surround two long ponds and marshy ground connecting them. On dead leaves beneath Rhododendrons, *Physarum sinuosum, Craterium leucocephalum, Leocarpus fragilis* and *Diachaea leucopoda* were found; the latter also occurred on moist herbage near the ponds; *Diderma testaceum* was gathered on dead bracken.

Physarum nutans in perfect condition was in great profusion almost everywhere on dead wood. Sept. 23rd Trench Woods, consisting of hazel, some ash, alder and a few scattered oaks, proved to be dry. Among the thirteen species of Mycetozoa obtained were our only gatherings of *Didymium squamulosum*.

The following is a list of the species recorded, with their distribution in the woods visited.

W. = Wyre Forest. *O.* = Ockeridge and Monk Woods. *S.* = Shrawley Wood. *T.* = Trench Woods.

Ceratiomyxa fruticulosa (Müller) Macbr. *W.O.S.T.*
Badhamia utricularis (Bull.) Berk. *W.O.S.T.*; seen in plasmodium only.
Physarum nutans Pers. *W.O.S.T.*
,, ,, subsp. *leucophaeum W.O.S.T.*
P. viride (Bull.) Pers. *O.*
P. cinereum (Batsch) Pers. *S.*
P. sinuosum (Bull.) Weinm. *S.T.*
Fuligo septica (L.) Gmel. *W.*
Craterium leucocephalum (Pers.) Ditm. *S.T.*
Leocarpus fragilis (Dicks.) Rost. *W.S.*
Diderma testaceum Pers. *S.*
Diachaea leucopoda (Bull.) Rost. *S.*
Didymium difforme (Pers.) Duby. *O.*
D. Clavus (Alb. and Schw.) Rabenh. *O.*
D. nigripes Fries. S. and var. xanthopus (Fries) List. *O.*
D. squamulosum Fr. *T.*
Stemonitis fusca Roth. *W.O.S.T.*
S. herbatica Peck *O.*
S. ferruginea Ehrenb. *S.*
S. hyperopta Meyl. *O.S.*
Comatricha typhoides (Bull.) Rost. *W.O.*
C. nigra (Pers.) Schroet. *W.O.S.T.*
Cribraria argillacea Pers. *W.O.*
Tubifera ferruginosa (Batsch) Gmel. *W.*
Reticularia Lycoperdon Bull. *O.*
Lycogala epidendrum (L.) Fries *W.O.S.*
Trichia affinis de Bary. *W.O.S.T.*
T. scabra Rost. *S.*
T. persimilis Karst. *O.S.*
T. varia Pers. *O.*
T. decipiens (Pers.) Macbr. *W.O.S.*
T. Botrytis Pers. *O.*
Arcyria cinerea (Bull.) Pers. *O.S.*
A. pomiformis (Leers) Rost. *W.O.S.*
A. incarnata Pers. *W.O.S.T.*
A. denudata (L.) Wettst. *W.O.S.T.*
A. nutans (Bull.) Grev. *W.O.S.T.*
Perichaena corticalis (Batsch) Rost. *W.*

It may be noted that *Diachaea subsessilis* Peck, first recorded for Worcestershire by Mr E. Brazier, who gathered it near Stourbridge in November 1920, was obtained about the same time in Wyre Forest by Dr W. T. Elliott; this specimen is without any lime deposits, and was so inconspicuous that it was unnoticed for some months after gathering.

LICHENS FOUND DURING THE WORCESTER FORAY.

By H. H. Knight, M.A.

The woods generally in the Midland Counties have a poor Lichen Flora, and this was the case with those visited during the Foray. Also the northern part of the County may perhaps suffer from the smoke of the industrial towns of the Birmingham district.

In Ockeridge and Shrawley Woods the most noticeable feature was the abundance of *Calicium hyperellum* and *Chaenotheca melanophaea*, both growing on oaks. Another of the Caliciaceae, *Cyphelium inquinans*, was plentiful on old gates outside Trench Woods. Graphidaceae were scarce in all the woods, and *Graphis elegans* was seen on only one tree. A few saxicole species were noticed on walls by houses, and two common species of *Verrucaria* were found on Lias stones outside Trench Woods. Specimens of *Umbilicaria pustulata* gathered on Malvern Hills the previous week were exhibited at the meeting.

W. = Wyre Forest. *O.* = Ockeridge and Monk Woods.
S. = Shrawley Wood. *T.* = Trench Woods.

Chaenotheca melanophaea Zwackh. *O.S.*
Calicium hyperellum Ach. *O.S.*
Cyphelium inquinans Trev. *T.*
Peltigera canina Willd. *S.T.*
Parmelia physodes Ach. common.
P. caperata Ach. *S.*
P. saxatilis Ach. *W.*
P. sulcata Tayl. *O.S.*
P. dubia Schaer. *S.*
P. fuliginosa Nyl. var. laetevirens Nyl. common.
Evernia prunastri Ach. common.
Ramalina fastigiata Ach. *O.*
Usnea florida Web. var. hirta Ach. common.
Xanthoria parietina Th. Fr. on roofs etc.
X. lychnea Th. Fr. *T.*
Candelariella vitellina Müll.-Arg. *O.T.*
Lecanora subfusca Ach. var. allophana Ach. *O.S.*
L. campestris B. de Lesd. *O.T.*
L. galactina Ach. *O.*
L. varia Ach. common.
L. conizaea Nyl. *O.S.*
L. symmictera Nyl. *T.*
Pertusaria faginea Leight. common.
P. pertusa Dalla Torre and Sarnth. *O.S.*
P. leioplaca Schaer. *O.S.*
Phlyctis agelaea Koerb. *S.*
Cladonia fimbriata Fr. *W.S.* var. subcornuta Nyl. *W.*
C. pityrea Fr. *W.*
C. macilenta Hoffm. *S.*
C. bacillaris Nyl. *W.*
Lecidea ostreata Schaer. *W.O.*
L. coarctata Nyl. *W.*
L. uliginosa Ach. *S.*
L. parasema Ach. *S.T.*
Biatorina Griffithii Massal. *O.S.T.*
Buellia canescens de Not. *T.*
B. myriocarpa Mudd *T.*
Opegrapha herpetica Ach. *S.*
O. varia Pers. *T.*
O. vulgata Ach. *T.*
Graphis elegans Ach. *S.*
Verrucaria nigrescens Pers. *T.*
V. muralis Ach. *T.*
Arthopyrenia fallax Arn. *O.S.*
Porina carpinea A. Zahlbr. *S.*
Pyrenula nitida Ach. *S.*

PRESIDENTIAL ADDRESS.

By Carleton Rea, B.C.L., M.A., Hon. member British Mycological Society, etc.

A BRIEF REVIEW.

Twenty-five years ago the British Mycological Society was founded by a small band of enthusiastic mycologists at Selby, on the 19th of September, 1896. It was felt that the formation of such a club would fill a long-felt want. At that date there were comparatively few students of our fungi, mycologists were often unacquainted with each other, they had no place of meeting, and there was no journal exclusively devoted to this branch of botany. Hitherto these wants had been met to some extent by the fungus forays of the Woolhope Club, and the mycological papers published in *Grevillea*. These forays were inaugurated by Dr H. G. Bull in 1867 at Hereford and were continued annually with great success until his decease on the 31st of October, 1885, but afterwards languished and finally ceased in September, 1892. The last number of *Grevillea* was published in June, 1894, on the completion of the twenty-second volume. A circular letter was subsequently sent out in the following November addressed to the leading mycologists and Natural History Societies and about fifty members were enrolled in response thereto. These included Professor J. W. Carr, Messrs W. N. Cheesman, A. Clarke, Rev. F. K. Clarke, Messrs M. C. Cooke, Charles Crossland, Rev. Canon J. M. Du Port, Mr W. H. Edwards, Revs. W. L. Eyre, W. Fowler, H. P. FitzGerald, Messrs T. Gibbs, T. Hey, Professor T. Johnson, Dr P. Magnus, Dr Philip Mason, Mr George Massee, Dr E. McWeeney, Mr J. Needham, Dr H. G. Peacock, Mr Greenwood Pim, Dr C. B. Plowright, Professor M. C. Potter, Dr N. Rehm, Mr J. B. Robinson, Miss E. A. Rose, Mr J. Rose, Professor E. S. Salmon, Messrs M. B. Slater, H. T. Soppitt, Professor J. W. H. Trail, Dr Harold Wager, Professors H. Marshall Ward, F. E. Weiss and the Dublin and Woolhope Naturalists' Field Clubs. Some of these names still appear in our list of members whilst others have filled the presidential chair; and we all are greatly indebted to the Rev. W. L. Eyre for his kind assistance in bearing the cost of many plates for our *Transactions*. Mr George Massee in his presidential address to the society at its first meeting in September 1897 in Sherwood Forest, dealt with "Mycological progress during the last sixty years" and therein referred to the valuable work done by Berkeley and the brothers

Tulasne, and the important discoveries made by de Bary and Brefeld by means of pure cultures. Since that date we have had several other presidential addresses and papers devoted to the early workers with fungi and mycetozoa and their first appearance in our literature, and I thought that perhaps it would not be out of place if I directed your attention to-night to the progress that has been made in some branches of mycology since the foundation of this Society.

In 1900 Monsieur N. Patouillard published his brilliant "Essai taxonomique sur les familles et les genres des Hyménomycètes," which I ventured to outline at some length in my presidential address delivered to this Society at Drumnadrochit in September 1908. Patouillard in this work formulates a scheme of classification of the Basidiomycetae based on a study of the basidium and other microscopical characters. This classification is quite different from the old Friesian system of classification and brings together nearly related genera which were formerly kept far apart, such as Cantharellus and Craterellus, and Boletus and Paxillus. Whilst the old heterogeneous species included in the Thelephoraceae are now assigned to their appropriate places, such as *Thelephora sebacea* (Pers.) Fr. and *Corticium calceum* (Pers.) Fr. which are now transferred to *Sebacina incrustans* Tul. and *Sebacina calcea* (Pers.) Bres., I must say that I have been greatly disappointed to find that few British mycologists, with the exception of those who have devoted their attention to the study of our resupinate fungi, seem to appreciate the importance of this reclassification. They continue their studies as if nothing had happened to disturb the old Friesian system and pay hardly any attention to distinctive microscopical characters. I feel convinced that these are of fundamental importance and that any book that may be subsequently published on the British Basidiomycetae will have to be based on these characters. Between the years 1906 and 1908 Dr Franz von Hoehnel and Viktor Litschauer published some interesting papers on the Corticia under the title "Beiträge zur Kenntnis der Corticieen" which clearly showed that the species in Corticium and allied genera could only be recognized by a careful microscopical examination. They showed that many specimens published in several well-known exsiccati were wrongly named, and often belonged to other genera, whilst in a few instances they were based on scraps of paint or insect workings. von Hoehnel has also published many valuable descriptions of fungi in his numerous contributions entitled "Fragmente zur Mycologie" which have appeared in the Transactions of the Vienna Academy (Sitz. der Kaiserl. Akad. Wissenschaft.) between the years 1902 and 1914. I would more particularly draw your attention to his

regrouping of the species of Mycena contained in his fifteenth "Fragmente," 1913. In this he rearranges the species on a system based upon the cystidia which we all know are generally present in most of the species of this genus. His classification is founded on their presence or absence, their occurrence on the gill edge only and also on the gill surface, their coloured or colourless contents, their early deliquescence or permanence, and their various shapes. I think it will probably interest you if I show you how this applies to our British species according to his investigations.

A. Cystidia small, oval, shortly setulose, *soon entirely deliquescent*: *Mycena viscosa* (Secr.) Maire, *Mycena epipterygia* (Scop.) Fr.

B. Cystidia permanent.
- 1. With coloured contents.
  - *α*. On gill edge only.
    Sharply pointed above, ventricose below: *Mycena avenacea* (Fr.) Schroet., *Mycena rosella* (Pers.) Fr., *Mycena rubromarginata* Fr., *Mycena sanguinolenta* (A. & S.) Fr.
  - *β*. On gill surface also.
    - *a*. Globose, oval, setulose: *Mycena elegans* Fr.
    - *b*. Narrow, conical: *Mycena pelianthina* Fr.
    - *c*. Acutely pointed above, ventricose below: *Mycena rosella* (Pers.) sensu Schroeter.
- 2. With colourless contents.
  - *α*. On gill edge only.
    - *a*. Globose, oval, generally setulose: *Mycena corticola* (Pers.) Fr., *Mycena galericulata* (Scop.) Fr., *Mycena rugosa* Fr., *Mycena tenella* Fr., *Mycena vitrea* Fr., *Mycena vulgaris* (Pers.) Fr.
    - *b*. Oval, with few setae: *Mycena dissiliens* Fr.
    - *c*. Oblong, vesiculose: *Mycena pura* (Pers.) Fr.
    - *d*. Bluntly conical above, ventricose below: *Mycena lactea* (Pers.) Fr., *Mycena luteoalba* (Bolt.) Fr., *Mycena metata* Fr., *Mycena polygramma* (Bull.) Fr., *Mycena rorida* Fr., *Mycena stannea* Fr.
    - *e*. Cylindrical, filamentose: *Mycena filopes* (Bull.) sensu Schroet., *Mycena hiemalis* (Osb.) Fr., *Mycena polygramma* (Bull.) Fr., *Mycena stylobates* (Pers.)Fr.
    - *f*. Vesiculose, conical: *Mycena zephira* Fr.
    - *g*. Short, filamentose, indistinct: *Mycena citrinella* (Pers.) Fr.
    - *h*. Long, filamentose, often ventricose below: *Mycena flavipes* Quél., *Mycena rubella* Quél.

i. Variable in shape (filamentose to conical or vesiculose): *Mycena leptocephala* (Pers.) Fr., *Mycena stannea* Fr., *Mycena sudora* Fr., *Mycena alcalina* Fr.

β. On gill surface also.

a. Thick, rigid, filamentose: *Mycena gypsea* Fr.

b. Bluntish, conical: *Mycena vitilis* Fr.

c. Short, clavate, vesiculose, setulose: *Mycena crocata* (Schrad.) Fr.

d. Acutely conical, containing many oil drops: *Mycena parabolica* Fr., *Mycena speirea* Fr.

e. Filamentose to fusiform, contents watery: *Mycena galopus* (Pers.) Fr.

C. Cystidia absent: *Mycena cyanorhiza* Quél.

I have cited this last which is not British because I know of no British example of the section. I am aware that some observers consider there are no cystidia in *Mycena epipterygia* (Scop.) Fr. but I can confirm von Hoehnel's statement that they are present in very young specimens. Ever since I obtained a copy of this paper I have carefully examined a considerable number of the cystidia in the commoner species of Mycena and in the main I agree with von Hoehnel's description of them, but I certainly differ from Schroeter with regard to *Mycena filopes* (Bull.) Fr. This species is characterized by broadly pyriform, or obovate, minutely spinulose cystidia which form a compact layer on the gill edge, and are not cylindrical and pointed as Schroeter has described them. To appreciate the correct shape of the cystidia it is necessary to work with freshly gathered material as they alter considerably in form when kept in tubes or a tin box for a comparatively short time, and this applies more especially to the cylindrical and filamentose ones. In his sixteenth "Fragmente" von Hoehnel also lays considerable stress on the fact whether the basidium is provided with two or four sterigmata. I admit that this is a feature of some diagnostic value but I should be very loath to separate one species from another on this character alone, because one often notices basidia with two or four sterigmata on the same gill and in the Corticia and allied genera it is a very common feature. I think it is much better to describe a species as having basidia with two to four sterigmata than to make the form with two sterigmata a variety as Lange does with *Mycena lactea* (Pers.) Fr. var. *pithya* A. & S., or to treat it as the type as Lange does with *Mycena filopes* (Bull.) Fr. and refers the one with four sterigmata to the forma *tetraspora* Lange. In the following year, 1914, Lange published his revision of "The genus Mycena" in his "Studies in the Agarics of Denmark" which appeared in the Dansk. Bot. Ark.

Bind 1, No. 5. He therein regroups the species of Mycena with smooth spores into two divisions based on the characters of the cystidia. In the first, the CILIATAE, he places all those having their free apical portion conical, cylindrical, hair-shaped or subulate, and in the second, the GRANULATAE, he puts all those having clavate pyriform or obovate cystidia beset with warts or setae on their free portion. This is a very workable division of this genus and one that I think we might very usefully adopt, but it will take some time before we can work out the form of the cystidia in all our British species and therefore I crave the assistance of all our members in so doing.

In 1914, the eminent American mycologist, Professor E. A. Burt, commenced his splendid series of monographs on the genera of the Thelephoraceae of North America. Up to the present these include monographs of the following genera: Thelephora, Craterellus, Cyphella, Exobasidium, Tremellodendron, Eichleriella, Sebacina, Hypochnus, Septobasidium, Coniophora, Aleurodiscus, Hymenochaete and Stereum. These monographs are models of careful work and original research and are indispensable to a thorough knowledge of this group, and I feel that all students impatiently await the completion of this series. In 1909, l'Abbé H. Bourdot and A. Galzin began an account of the "Hyménomycètes de France" in the Bulletin de la Société Mycologique de France, vol. XXV, and several other instalments have appeared in succeeding years, but it is unfortunately far from completion at the present time. It is based on Patouillard's classification but is especially valuable for the wealth of detail that it gives respecting the Thelephoraceae, Hydnaceae, Auriculariaceae, Tremellaceae and Tulasnellaceae. They have in a great measure remodelled the definitions of the species of Thelephoraceae and resupinate Hydnaceae and in conjunction with the investigations of v. Hoehnel, v. Hoehnel and Litschauer, l'Abbé Bresadola and Professor Burt compelled us to reinvestigate our own British species in this group. It is somewhat unfortunate that Bourdot and Galzin have not followed the laws of international nomenclature and that they rarely condescend to say what name the new species described by them was previously known by to the older school of Friesian mycologists. Take *Odontia bicolor* (A. & S.) Bres. as an instance which Miss Wakefield has clearly shown was known to Berkeley by the name of *Grandinia mucida* Fr. Again, the well-known *Peniophora hydnoides* Cke. & Massee has no cross reference in their synopsis of that genus but suddenly crops up as *Odontia conspersa* Bres., a specific name that cannot be maintained under any rules of nomenclature. It is however a very important work and I think we are very grateful to Miss Wakefield and Mr A. A. Pearson for

applying these intensive studies to the investigation of our British resupinate Basidiomycetae. I consider also that I am justified in offering to them on your behalf our very hearty congratulations on having two new British species named in their honour by l'Abbé Bresadola and l'Abbé Bourdot, viz. *Corticium Wakefieldiae* Bres., and *Corticium Pearsonii* Bourd.

In 1915 Lange published further monographs on the genera Amanita, Lepiota and Coprinus in his "Studies in the Agarics of Denmark" (see Dansk. Bot. Ark. Bind. 2, No. 3), but it is only to this last one that I propose to draw your attention because I think the groups into which he has divided the species of Coprini are very natural ones and well worthy of adoption. He arranges them in three sections:

I. COMATI: Pileus when young covered by filaments made up of cylindric or irregularly branched cells;

II. FARINOSI: Pileus when young covered with meal or glistening particles formed of globose cells; and

III. NUDI: Pileus naked. Veil none.
- *α. Setulosi*: Pileus sparsely and minutely bristly or setulose under a lens.
- *β. Glabri*: Pileus quite bare and without setulae.

Lange unfortunately only deals with about half the number of the British species, so there is plenty of work for our members to do in determining to which section the omitted ones should be referred.

In 1907 the eminent French mycologist Emile Boudier published his "Histoire et classification des Discomycètes." This work further elaborates the excellent system of classification of the Discomycetae which this great master had first outlined in 1885 in the Bulletin de la Société Mycologique de France, I, 91. The great superiority of this system over all others is due to the fact that it is based on a careful investigation of all the microscopical characters, and related genera are brought into a natural instead of an artificial sequence. Boudier was the first mycologist to draw attention to the importance of the mode of dehiscence of the ascus in this group, and this constitutes the basis of his two main divisions, the *Operculeae* dehiscing by a circular opening furnished with a lid, and the *Inoperculeae* dehiscing by a simple apical orifice. In his original essay Boudier only assigned a few species to each genus but in his later work he gives a complete list of them. This made his scheme much easier to work with and shortly afterwards I ventured to record our British species under his genera in the lists of specimens collected at our forays. In 1913 Mr J. Ramsbottom made it available for the use of British students by publishing in our

Transactions an excellent "List of the British species of Discomycetes arranged according to Boudier's system, with a key to the genera." We are I fear very conservative in our ideas of the classification of our British Fungi as it appears that close on thirty years had elapsed between the first publication of Boudier's system and its adoption and now almost twenty years have passed since Patouillard propounded his revision of the Basidiomycetae. In 1910 Boudier completed his "Icones Mycologicae ou Iconographie des Champignons de France principalement Discomycètes." This is undoubtedly the very finest illustrated work on fungi that has ever been issued, and the minute microscopical details, beautifully portrayed on each plate, make it of the greatest value and assistance in the identification of species, and indispensable to the student of the Discomycetae.

In 1919 Mr A. D. Cotton and Miss E. M. Wakefield gave us a very valuable "Revision of the British Clavariae" (see Trans. Brit. Myc. Soc. VI, 164) founded on fourteen years' study of this genus by the former, and I think we are much indebted to them for giving us such a reliable monograph of our British species. I must however protest against *Clavaria dissipabilis* Britz. being treated as a synonym of *Clavaria inaequalis* (Müll.) Fr. because the former is distinguished from the latter by having echinulate spores. Cotton in a paper published in 1907 (see Trans. Brit. Myc. Soc. II, 163) maintains that this spore character must be attributed to *Clavaria inaequalis* (Müll.) Fr. and alleges that "the first reference to the character of the spores appears to be in 1882, in which year Karsten (Ryss. Finl. Skand. Hattsv. II, 171) describes these bodies as elliptical, $10 \times 5\,\mu$," but I feel confident that such eminent mycologists as Boudier and Patouillard would never have published their description of *Clavaria similis* in 1888, unless they had been satisfied that the true *Clavaria inaequalis* (Müll.) Fr. possessed smooth spores. It is generally admitted as Cotton states that *Clavaria similis* Boud. & Pat. is synonymous with *Clavaria dissipabilis* Britz. and must give way to the latter on the ground of priority. Cotton and Wakefield in the Monograph, p. 190, say "it is possible that a species with smooth, elliptical spores occurs on the Continent, but if so it is obviously very rare and cannot be regarded as representing the old and well-known *Clavaria inaequalis*." But the French assign a smooth ovoid spherical spore to *Clavaria inaequalis* (Müll.) Fr. Quélet in his "Flore Mycologique de la France" published in 1888 describes the spores, at p. 461, as "ovoïde sphérique, $7\,\mu$," and Bourdot and Galzin in the "Hyménomycètes de France" which appeared in 1910 in the Bulletin de la Société Mycologique de France, XXVI, 217, define the spores as "ovoides-sphériques, apiculées, $7–9 \times 6–8\,\mu$,"

and under *Clavaria similis* Boud. & Pat. describe the "spores hyalines à guttule huileuse, subsphériques, hérissées d'aiguillons coniques, $4–7 \times 4{\cdot}5\,\mu$" and further add that this species is "plus commun que *Clavaria inaequalis*." Thus if we allowed Cotton's contention to prevail we should have the absurdity of *Clavaria inaequalis* (Müll.) Fr. being represented by an echinulate spored species in England and a smooth spored species in France. I may also add that I possess a painting made by my wife in 1889 of a Clavaria which I referred to *inaequalis* (Müll.) Fr. and this had smooth, globose spores, $6–7\,\mu$ in diam., so it would seem clear that we also have the smooth spored form and it is probably not uncommon as I do not suppose that even one per cent. of these specimens are ever subjected to microscopical examination.

We have had numerous presidential addresses and papers showing the great progress that has been made in the study of the Uredinales, Ustilaginales and Perisporiales. We now know that many of the biological species on our cereals are confined to one host and it is only occasionally by means of a bridging species that they are enabled to attack another host: that certain strains of our cereals are immune or less liable to be affected, this immunity depending not so much on the inability of the spores of the parasite to effect an entrance but is rather due to some reaction on the host's part, probably in the nature of an enzyme, that arrests their further development. In 1904 Eriksson brought forward his well-known mycoplasm theory as the cause of epidemical rust and mildew outbreaks that otherwise could not be explained. His view is that this mycoplasm exists as a form of protoplasm within the cells of the host and that it lives symbiotically in the tissues of the plant until such time as favourable conditions, climatic and others, cause it to pass into the typical mycelial stage from which the spore-beds of the Uredo are formed. Great advances have been made by numerous workers in our knowledge of the heteroecious rusts and the "Monographia Uredinearum" by P. and H. Sydow contains an exhaustive account of this group, most of which has been embodied in W. B. Grove's "British Rust Fungi" published in 1913. For a reliable list of the British Uredinales we are indebted to Mr J. Ramsbottom who prepared the list for our 1912 Transactions (see Trans. Brit. Myc. Soc. IV, 98).

I know of no real progress being made during this period with regard to a reclassification of the Pyrenomycetae, which is at present based, as you all know, on an artificial scheme almost as crude in character as the Linnean system was for phanerogams: but notwithstanding this crudeness it is rather a remarkable fact and one I think to be deplored that no British text-

book has appeared dealing with this branch of mycology since Cooke's "Handbook of British Fungi" in 1871. It must not however be imagined that their study has been neglected as the contrary is evidenced by the numbers of additions to the British list that Miss A. Lorrain Smith has annually recorded in our Transactions and I feel that we are very greatly indebted to her for the magnificent series of papers on our micro-fungi which have so greatly extended our knowledge of the British species and are an undying monument to her skill and knowledge of these groups. Mr A. D. Cotton and Dr S. K. Sutherland have also given us invaluable papers on our Marine Pyrenomycetes (see Trans. Brit. Myc. Soc. III, 92 and IV, 147 and 257), and it is only in recent years that fungi have been discovered growing on our seaweeds.

In 1915 Mr J. Ramsbottom gave us an exhaustive "List of the British species of Phycomycetes, with a key to the genera" (see Trans. Brit. Myc. Soc. V, 304). He enumerates over one hundred and sixty species whereas the last British list, published by Massee in 1891, "British Fungi: Phycomycetes and Ustilagineae," included only about ninety British examples, and so we see that our knowledge of this group had almost doubled in this period. Mr Ramsbottom prefaced this list with a catalogue of the nine British species included in the Phytomyxineae or Plasmodiophoraceae, and the Acrasieae. It was only last year that Mr Norman G. Haddon made an addition to the former group by his interesting discovery of *Tetramyxa parasitica* Göbel which he found growing on *Ruppia rostellata**.

These last two orders belong to the Mycetozoa, but are not included in the magnificent and exhaustive Monograph of the Mycetozoa by Mr Arthur Lister and Miss Gulielma Lister which was published under the auspices of the British Museum in 1894 and 1911. This Monograph is beautifully illustrated, has accurate camera lucida drawings of all the microscopic details of each species founded on an examination of the types, and is provided with elaborate keys to the genera and species. I only regret that no such accurate text-books have yet appeared to assist the student in the various branches of mycology. The appearance of this Monograph greatly stimulated interest in these minute animals and this is proved by the fact that the first edition of the "Guide to the British Mycetozoa" issued in 1895 only enumerated one hundred and nineteen species whereas the fourth edition, published in 1919, has increased this to one hundred and eighty-one, an addition of over half the original number.

* We have since learned that this species was recorded by Mr D. A. Boyd in 1887 from Chapelton, West Kilbride (Trans. Nat. Hist. Soc. Glasgow, II, p. xxxvi (1888)).

During this period our knowledge of the life-history of many of our numerous fungal diseases, which attack fruit trees, bushes, cultivated crops and vegetables, has greatly increased. Hardly a day now passes but what some new species is added to the already long list of these pests. Various remedies are suggested for their suppression, amelioration, or avoidance. At the present time the planting of immune varieties and strains of fruit trees and vegetables, and the employment of protective washes to prevent infection seem to be most favoured. I think we may congratulate ourselves upon the fact that it was due to the strenuous efforts of two of our members, Prof. E. S. Salmon and Mr F. T. Brooks, that Government action was taken to suppress the Gooseberry Mildew, *Sphaerotheca mors-uvae* B. & C., and the Silver-leaf disease of our plum and other fruit trees attributed to *Stereum purpureum* (Pers.) Fr.

With regard to the cytology of fungus reproduction I feel that this requires no comments from me as it was ably dealt with by Dr Harold Wager in his luminous Presidential address on "The significance of sex and nuclear fusions in the fungi" (see Trans. Brit. Myc. Soc. VI, 307) delivered to you only two years ago. Mr J. Ramsbottom has also kept our members well abreast with the most recent investigations on this subject by his voluminous, exhaustive and able summaries of the results obtained throughout the world (see Trans. Brit. Myc. Soc. III, 354; IV, 127, 249; V, 85, 271 and 441).

I claim also that an immense advance has been made in the knowledge of our larger British fungi by the members attending our annual spring and autumn forays. Since the meeting at the Boat of Garten in September, 1900, complete lists of all the species gathered have been published, and each year increases the value of these as a reliable source upon which to base the data for the distribution of our fungi.

Perhaps the most noteworthy forays that have been held may be considered to be those at Forres and Baslow. The former was held in conjunction with the Cryptogamic Society of Scotland from the 12th to the 19th of September, 1912, under the Presidentship of Miss Gulielma Lister. At this meeting seven hundred and twenty-six species of fungi and eighty-one species of mycetozoa were collected. It is not fair to compare this number with those collected at other autumn forays because a certain number of our members arrived at Forres several days before the meeting and their collections are included in this large total. It is clear however that the climatic conditions were very favourable to their growth, because in 1919 at the autumn foray held at Baslow from the 22nd to the 27th of September, under the Presidentship of Dr Harold Wager, only three hundred and

ninety-one species of fungi and forty-five species of mycetozoa were met with although many of the members were detained there for a week longer owing to the railway men's strike. The chief cause of this poor record was undoubtedly the early advent of severe night frosts, which killed the mycelium after it had begun to run. At the autumn foray held at Baslow, Derbyshire, from the 27th of September to the 2nd of October, 1909, under the Presidentship of Professor M. C. Potter, the Society was greatly honoured by the attendance of several distinguished French mycologists including Professeur René Maire, Mons. E. Peltereau and Mons. and Mme. E. Simon. It was due to their kind assistance that many important additions were made to the British fungus flora. These included *Omphalia Allenii* Maire, named in honour of my friend and fellow-member Mr W. B. Allen, one of the most able discriminators of species in the Basidiomycetae, and *Leptonia Reae* Maire, named in honour of my wife as a tribute of his admiration for her paintings of our fungi. Over five hundred and thirty-three species of fungi and forty species of mycetozoa were passed in review during the week, and Dr René Maire subsequently created a new variety of *Leptonia serrulata* (Pers.) Fr. for the form that exactly corresponded with the painting by Berkeley erroneously reproduced as the type in Cooke's Illustrations of British Fungi, No. 355, t. 333, and based on specimens collected at Spondon in Derbyshire, calling it var. *Berkeleyi* Maire in honour of that distinguished mycologist.

I found on referring to our Transactions for the exact date of this meeting, that Professor M. C. Potter delivered a very instructive Presidential address on "Bacteria in their relation to plant pathology" (see Trans. Brit. Myc. Soc. III, 150). Professor Potter pointed out that many plant diseases were caused by these parasites, in many other cases they were found in association with parasitic fungi, and that it was often very probable they were the primary cause of the infection. Professor H. Marshall Ward in an early Presidential address (see Trans. Brit. Myc. Soc. I, 124) insisted on the importance of these organisms in converting xylose into some other form of sugar more easily assimilated by fungi. We all know that many orchids and heaths can only be successfully raised from seeds that at an early stage are brought into contact with the symbiotic, endotrophic mycorrhiza, and that some observers allege that the presence of bacteria is essential to the germination of the spores of some species of Coprinus and mycetozoa. The study of the bacteria causing plant disease is a very important and interesting one, but I fear that it is impossible for many of our members to take up this branch of mycology because

the student needs a well-equipped laboratory for his investigations. In 1909 Professor A. H. R. Buller published his "Researches on Fungi," which is an invaluable work embodying the results of original research on the physiology of our fungi and it is to be hoped that he will favour us with another volume on the same subject.

I have now passed in brief review the most important features of our mycological progress that has been made since the foundation of our Society. I think that we can congratulate ourselves on the fact that, although many of our junior members were called away during the war, we managed to carry on, to hold our autumn forays and to publish our Transactions as usual. We have emerged from that trying time stronger in number than we ever were before and I feel confident all our members will continue to advance our knowledge and uphold our motto "Recognosce notum, ignotum inspice."

THE PARASITISM OF NECTRIA CINNABARINA (CORAL SPOT), WITH SPECIAL REFERENCE TO ITS ACTION ON RED CURRANT.

With Plate I.

By J. Line, M.A.

General.

This subject has been investigated by a number of workers, but although the very familiar fungus is regarded in this country as a frequent parasite on many broad-leaved trees, no critical investigation appears to have been made, nor has it been considered as the cause of any serious damage.

Mayr (1) demonstrated by actual infection experiments as long ago as 1883 that the fungus could become parasitic on maple: although he did not use pure cultures of the fungus there seems no reason to doubt the general accuracy of his results.

He pointed out that the normal method of infection was through a wound, and that the fungus could not penetrate the living phloem and cortex. He also showed that the fungus when established in a side branch could readily pass over into the healthy wood of the main stem, and that the pathological effect was primarily due to the blocking of the vessels by the hyphae, causing death of all parts above the point affected. The stem so killed was then easily and rapidly invaded by the fungus, although the first blocking process might take two years or considerably more.

It is almost impossible to reconcile these results with those of Wehmer(2) who from observations on the lime and hornbeam in 1894 concluded that the fungus became parasitic, but that it was strictly confined to the cortical regions, never entering the woody tissues. He considered that Mayr was completely mistaken in his observations or that he was working with another fungus.

Durand(3) in 1897 described the appearance of the fungus on red currant in the U.S.A., his descriptions of the disease tallying exactly with the symptoms observed during 1919 and 1920 in this country. He considered that it was acting as a parasite, but although he performed infection experiments with pure cultures of the fungus, he does not record any of his results. It is well known that coral spot often occurs on dead branches of otherwise healthy red and black currant bushes in this country. It was pointed out to the writer in 1919, by Mr F. T. Brooks, that it had never been shown how much of the die-back observed was due to the primary action of the Nectria, and how much to the action of one or other of the fungi often associated with it.

An investigation was therefore started in order to settle if possible

(1) to what extent the fungus may be regarded as a parasite, particularly on the red currant;

(2) its normal method of infection and method of growth in the host tissues;

(3) whether any differences in power of infection could be detected between different strains of the fungus.

Field Observations.

A number of orchards were kept under fairly close observation during the years 1919 to 1921, and a very large number of the bushes were found bearing the stromata of Nectria on one or more of their branches. Other commonly occurring fungi were *Collybia velutipes* and *Fomes Ribis*. A few bushes were found bearing *Stereum purpureum* and Botrytis. No experimental work was done with these fungi, but a short summary of observations made on them will be found elsewhere.

During this preliminary examination of the bushes, single branches on apparently healthy bushes were often found showing signs of wilting of the leaves. In some cases this was observed just after the leaves had expanded, but others did not become wilted until about flowering time. Later on branches bearing nearly ripe and quite normal fruit were found suddenly to become wilted (Figs. 1 and 2). Such branches when left on the bush were observed to lose all their leaves during the summer,

and to become completely dried up: in all about fifty branches were kept under close observation from the time wilting was first observed, and in every case the branch which had lost its leaves became covered with the pink stromata of Nectria during the following winter.

A number of similar branches were removed from the bushes as soon as the wilting was observed. When cut open it was found that a brownish green region was present in the wood at the base, extending almost across the branch, leaving a small area of white and healthy wood, with a corresponding area of healthy cortex external to it.

This discoloured portion could always be traced either to a wound in the branch itself or more commonly to a dead side branch; in many cases these dead portions already bore stromata of Nectria.

The discoloured portions of wood and cortex were found to be full of fungus mycelium extending up to the edge of the white and healthy wood, the vessels and tracheids being choked up in the darker parts with hyphae and gummy material. This characteristic discoloration of the wood was observed by Mayr in the wood of Norway maple, and he considered the gummy liquid represented the product of solution of part of the cell wall by the fungus. Fig. 3 shows the hyphae in the wood cells taken from the edge of the discoloured zone; it is seen that in the early stages of invasion the fungus appears incapable of invading the living ray cells; later on these also become filled with hyphae. It was never found that the fungus advanced in the cortex before the wood was blocked up, in fact there seemed no evidence that it could effect an entrance into any living cell in a normal healthy condition.

Experimental Work.

A. *In the laboratory.*

Twelve typical branches were selected with discoloured portions attached to them, but no visible stromata or signs of the presence of any fungus upon them; after thorough scrubbing they were placed under sterile conditions in jars of water under bell jars. In six weeks every branch began to show the pink stromata of Nectria breaking through the bark, commencing round the discoloured regions. (Control branches developed a little Cladosporium under these conditions.)

Portions of the wood from different parts of the discoloured regions were removed from another batch of branches under sterile conditions and were transferred to Petri dishes of sterile agar jelly.

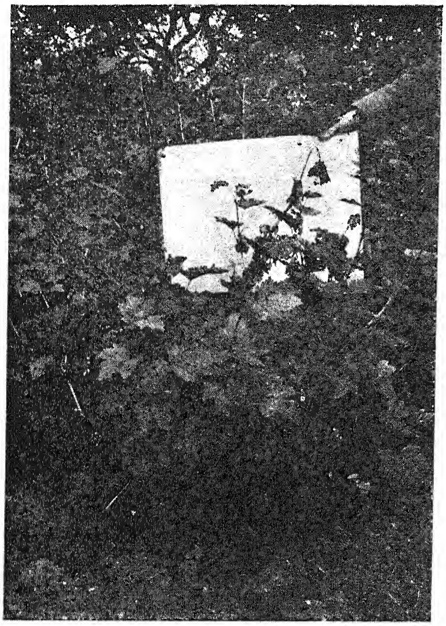


FIG. 1.

FIG. 2.

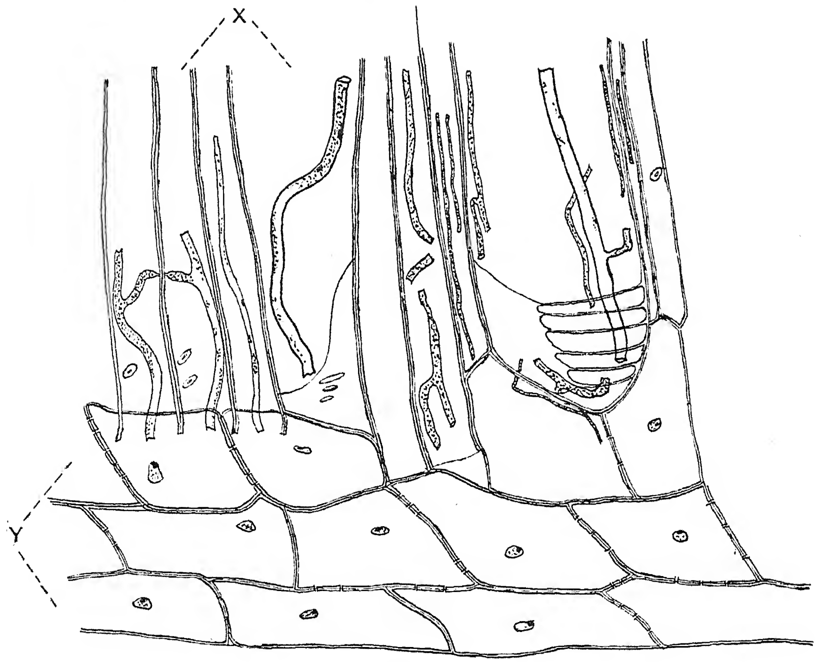


FIG. 3.

FIG. 1. First signs of wilting of twig of red currant.
FIG. 2. Later stage of wilting of twig of red currant. Note the nearly ripe fruit on this branch.
FIG. 3. Long. radial section of wood of red currant. Mycelium of *Nectria cinnabarina* invading the healthy wood. Note absence of hyphae from the ray cells. ×350 approx. X = xylem elements. Y = ray cells.

From a number of these dishes nothing developed, but in all cases where the piece of wood had been taken from the edge of the dark zone a vigorous fungal mycelium grew out from the chip into the jelly. Portions of this mycelium could be readily removed to other media, and in all such cases the mycelium proved to be that of Nectria.

From these observations and experiments it seemed probable that the Nectria was able to cause the wilting and death of branches on the currant when once established in the bush. It is worth recording that in no single case did Botrytis develop from the cultures made from the branches, and it was observed comparatively rarely in the orchards. *Collybia velutipes* was extremely common in one orchard on older bushes, and was then frequently associated with Nectria; it was rarely found on younger bushes and did not develop on any of the bushes from which wilted branches were removed. About a dozen bushes in all were found bearing fructifications of *Fomes Ribis*; these were in every case sickly looking plants stated to be at least forty years old.

B. *Infection Experiments in the field.*

The common occurrence of the fungus on so heavily pruned a plant as the red currant, as well as its behaviour on other plants, would lead one to suppose that its normal method of entering the host was through a wound; in view of some recent work on the method of infection of the apple canker fungus it was decided to test the power of the coral spot fungus to penetrate uninjured branches, through either the leaf-scars, lenticels or bud scales.

It was thought possible that different strains of the fungus might be found which would show different powers of infection. A series of cultures of the fungus was started with the usual precautions as to freedom from other fungi, bacteria, etc. No difficulty was experienced after a time in making single spore cultures from both conidia and ascospores, and these were obtained from a number of different sources. Cultures were set up on many different media under a variety of conditions in the hope that the formation of perithecia might be induced. So far none have been obtained, although nodules exactly resembling them in appearance and to some extent in structure are obtained in old cultures. These cultures are being carried on with other media at the present time, in the hope that the success of Miss Cayley with *Nectria galligena* may be repeated.

This fungus shares with *Nectria cinnabarina* the character that in many gelatinous media the mycelium buds off spores laterally in great profusion.

Infections were made on red currant (200), fig (20), lime and horse-chestnut (20) in a number of different ways and at different times of the year. Wounds made were of course protected from chance contamination from outside sources.

The cortex and wood were inoculated at varying depths; mycelium and spores were placed on leaf-scars of different ages and between the scales of resting buds. In most cases the mycelium from wood block culture was used, but conidia and mycelium from agar cultures, ascospores and conidia from natural sources were also used.

It was found in the case of the red currant that the fungus made very little progress indeed in the cortex and phloem, or in the wood of a healthy branch. When severely wounded by a deep incision some headway was made, but in two cases only did the fungus establish itself and produce fructifications on the branch.

As a rule a small discoloured area was formed round the point of inoculation and this did not increase. Callus formation rapidly covered the wound with healthy tissue, and by the following year the only trace of the inoculation was a small dark area in the wood.

In the case of the horse-chestnut and lime several branches were found in which the fungus made rapid headway, fructifications of Nectria being formed in about three months. In other cases on the same trees the fungus was apparently isolated and unable to make headway.

The observations on naturally occurring infections suggest that the fungus can attack healthy wood when it is established in a dead portion adjoining the healthy part. A series of infections were therefore made on artificially killed branches projecting from healthy branches. Some were killed by severe longitudinal slitting, others by means of a steam jet or the flame of a spirit lamp. All were covered up for some days before inoculation.

The fungus was found to establish itself fairly readily in these killed side shoots, stromata being developed sometimes in six weeks. After a period which was variable, but never less than six months, the fungus began to work its way into the main stem, stromata appearing on the side from which the shoot projected. In time the whole stem was blocked, exactly the same symptoms being observed as have been described previously from field observations.

Conclusions.

It would seem probable that this fungus resembles others which have been described recently in that it cannot establish

itself directly in healthy tissues, but that it can do so after a period spent on a dead portion of the host.

It is thought that the harmful action of the fungus is entirely due to its growth in the xylem elements, causing death of living cells above the infected area owing to water shortage.

No evidence was obtained that it could ever enter a living cell until the cell was at any rate partially cut off from its water supply. No ill effects appear to be felt by the leaves and flowers on a stem, which may be almost completely blocked with Nectria at a lower level, until they suddenly show signs of wilting. It therefore would seem improbable that any toxic substance is secreted by the fungus which can affect living cells in advance of the fungal hyphae. Experiments are being conducted with a view to further elucidation of this point.

It is commonly observed that the attacks of the fungus are much more frequent on red currant than on either black currant or gooseberry. The former, which is normally somewhat heavily pruned, furnishes a number of dead spurs each year, and these are observed to be the starting-points of the fungus in the great majority of cases. The time of the actual invasion of the main stem is not apparently related to the time at which the first infection took place. Observations show that the older bushes suffer more serious damage from the fungus than younger and more vigorous bushes of the same variety, but it is plain that the fungus has in most cases been growing for several years on the older bushes before actual death of branches on a large scale occurs.

Very little information could be obtained as to the names of varieties in the orchards, although it was certain that differences in the extent of attack by the fungus under the same conditions did exist. Further work is being done in collecting evidence as to the different varieties, and the effect of soil conditions.

Summary.

(1) The fungus was not found capable of effecting an entry into uninjured plant tissues.

(2) It can occasionally establish itself when introduced into a wound in certain woody plants, more readily in the case of the lime and horse-chestnut than in the case of the red currant, but it usually failed to do so under the conditions of the experiments.

(3) Its normal method of attacking the red currant is by spreading through the wood cells from a dead portion into the healthy wood.

(4) Its harmful action in the first place is due to the stoppage

of the wood cells by the fungal hyphae, thus causing wilting and death of all parts above the point affected.

(5) No differences in power of infection or in behaviour in culture were observed between strains of the fungus isolated from different sources.

I should like to take this opportunity of thanking Mr F. T. Brooks for the time he has spent in directing the work and for many suggestions and criticisms, and Professor Seward for laboratory accommodation.

REFERENCES.

(1) MAYR, H.—Über den Parasitismus von *Nectria cinnabarina*. Unters. aus d. Forstbotan. Institut. zu München, III, pp. 1–6 (1883).

(2) WEHMER, C.—Zum Parasitismus von *Nectria cinnabarina* Fr. Zeitsch. f. Pflanzenkr. IV, pp. 74–84 (1894).

—— Einige weitere Beiträge zum Parasitismus der *Nectria cinnabarina* (Td.) Fr. Ibid. v, pp. 268–276 (1895).

(3) DURAND, E. J.—A disease of currant canes. Cornell Univ. Agric. Exp. Stat. Bot. Div. Bull. 125, pp. 21–38 (1897).

Other references to literature will be found in the 3rd edition of P. Sorauer's Handbuch der Pflanzenkrankheiten, II, p. 205 (1906).

ORCHID MYCORRHIZA*.

With Plates II—VII.

By J. Ramsbottom.

INTRODUCTION.

One of the most interesting phenomena in biology is that generally known as *symbiosis*—the living together of two organisms in close association. It is usually considered that this intimate relationship is of benefit to both components. Many examples occur in the plant kingdom. The lichen is probably the best known of these, being a composite plant formed of a fungus and an alga in definite union. Other well-known examples are the bacteria (*Pseudomonas radicicola*) living in the root nodules of Leguminosae, and the Ginger-beer plant†, of which the lumps are composed of a yeast (*Saccharomyces pyriformis*) and a bacterium (*Bacterium vermiforme*). An intimate union can also occur between plant and animal, as in the case of the marine worm *Convoluta*, in the body of which an alga is always present,

* Reprinted from Messrs Charlesworth and Co.'s Catalogue, 1922. The Editors desire to thank Messrs Charlesworth for permission to reprint this article and for the loan of the blocks.

† The Ginger-beer plant is, at the present time, being widely distributed over the country as "Californian Bees," "Macedonian (Salonika) Bees," "Mesopotamian Bees," "Palestine (Jerusalem) Bees," "Wine Bees," "Water Bees," "Balm of Gilead," etc.

and as in the larvae of certain aphids, coccids, etc., where yeasts occur as more or less definite structures.

Mycorrhiza.

That the roots of many plants have the threads or mycelia of fungi associated with them has become very well known during the last eighty years. It is of interest to find that cells containing fungi were first figured in an orchid (though not very clearly) by Link* in 1840, who observed them in the young seedling (protocorm) of *Goodyera procera*. He did not hazard a guess as to their nature—his idea being that the cells were filled with colourless granular material which finally disappeared.

At the beginning of the forties of last century the naturalists of this country who were curious in botany were very interested as to whether *Monotropa Hypopitys* was parasitic on the roots of beech in a manner similar to *Lathraea*. In 1842 we have T. G. Rylands† writing "On the nature of the byssoid substance found investing the roots of *Monotropa Hypopitys*." Rylands concludes that "the 'byssoid substance' is really fungoid, and performs no essential function in the economy of the *Monotropa*." It is, however, to Reissek‡ (1847) that we owe our first real knowledge. He examined numerous plants and came to the conclusion that fungi were normally present within the cortical cells of the roots of various flowering plants, being best developed in the underground roots of orchids. In these he studied most of the native and several exotic genera. He found that in *Orchis Morio*, for example, the fungus was present in almost all the cortical cells, whereas in the tropical species the fungal masses were arranged singly at the periphery. The presence of fungi was most frequent in underground roots, less usual in superficial ones and very rare in aerial roots exposed to the light. Moreover Reissek attempted to extract the fungus from the roots. In those days of imperfect technique it is not so surprising that he failed as that he should have made the attempt. The fungus he obtained he named *Fusisporium endorhizum*: it is probably one of the common saprophytic species of *Fusarium* so abundant in soils.

Another type of association between fungus and root is also well known, particularly in forest trees. Here the fungus mycelium forms a sort of mantle round the root, in contrast to being within the cells of the cortex. Apparently Hartig first

* H. F. Link, Icones selectae anatomico-botanicae, II, p. 10, t. VII (1840).

† T. G. Rylands, On the nature of the byssoid substance found investing the roots of *Monotropa Hypopitys*. Phytologist, I, pp. 341–8 (1842).

‡ S. Reissek, Über Endophyten der Pflanzenzelle, eine gesetzmässige den Samenfäden oder beweglichen Spiralfasern analoge Erscheinung. Naturwiss. Abhandl. von W. Haidinger, I, pp. 31–46 (1847).

noted this type in 1840 in the extremities of the rootlets of *Pinus sylvestris* although he mistook the hyphae for branched intercellular canals surrounding the internal cells such as are known to exist in the corky layer of the root cortex in *Juniperus* and *Thuja*. Rootlets so infected are most frequently coralloid in appearance. Gasparini in 1856 noted that such rootlets in *Castanea* and *Corylus* were surrounded by fungal hyphae.

The term *mycorrhiza* was coined by Frank* in 1885 for the fungus-roots. Even at that date it was known that in some plants the fungus occurred in rhizomes as well as roots (e.g. *Neottia*), and since then many cases have been found for which the term is quite a misnomer (e.g. Liverworts). It is a convenient term, however, and it is better to accept it with an extended meaning rather than to restrict it to those cases for which it is etymologically sound. Frank gave special names to the two types mentioned above. He used the term *endotrophic* mycorrhiza for those forms in which the fungus occurred within the tissues of the host, and the term *ectotrophic* mycorrhiza where the fungus hyphae surrounded the rootlet as a sheath. These are convenient general terms, but it is well to remember that the two types are not absolutely distinct, as is seen, for example, in *Monotropa*, which had been well described by Kamienski in 1883. Mycorrhizas, mainly endotrophic, have been described, either as usual, or occasional, in various Liverworts, Mosses, Horsetails, Club Mosses, Adder's Tongues, Ferns, Conifers and Flowering Plants: and in Algae apart from Lichens we have cases of constant association of fungi and seaweeds, as, for example, in *Ascophyllum* and *Pelvetia*, which each have their attendant *Mycosphaerella*. The antiquity of such associations is seen in the fact that they occur in the fossil plants *Rhynia*, *Hornea* and *Asteroxylon* from the Lower (or Middle) Devonian —vascular cryptogams which from their simple structure and age are of the greatest theoretical importance. Weiss (1904) moreover recorded mycorrhiza in fossil roots from the Lower Coal Measures for which he proposed the name *Mycorrhizonium*, and Osborn (1909) found fungus mycelia in the inner cortex of *Amyelon radicans*, the root of *Cordaites*.

Orchid Roots.

As we have seen, fungi have been recognised in the roots of orchids since 1847. A transverse section of an infected root taken just above the root-cap shows the fungus in the cortical cells (Fig. 1). The distribution is more or less constant in the

* A. B. Frank, Ueber die auf Wurzelsymbiose beruhende Ernährung gewisser Bäume durch unterirdische Pilze. Ber. d. deutsch. bot. Gesell. III, pp. 128–145 (1885). Lehrbuch der Botanik, Bd. I (1892), p. 264.

same orchid, but varies in different genera. It is only in the young root where root-hairs are present that the fungus is, as a rule, recognisable as such. The epidermal cells are not infected. The fungus usually enters the root through the root-hairs, but in some species it apparently is able to make use of any portion of the piliferous layer. The hyphae* pass through the external layers to a more or less definite zone, where they reach their maximum development, rapidly spreading and completely filling the cells. If an exodermis be present the hyphae pass through the thin-walled transfusion or passage cells. The first two or three cortical layers of the root are thus generally free from fungus except where the hyphae of infection pass through them: even in these there is no balling of the mycelium in the cells. In some genera (*Habenaria*) (Figs. 1 and 14), the fungal zone occupies roughly the third and fourth layer of cortical cells. In other genera (*Neottia* and *Epipogum*) the fungal zone of the root occupies three layers or so of cells separated from the endodermis by about half-a-dozen cell rows. In other cases practically the whole of the cortex is occupied (*Cymbidium* and *Odontoglossum*). The central stele is never infected, the mycelium not entering the endodermis. The fungus also never infects the cells of the growing point of the root. Infected roots do not always show the endophyte in all their length, neither is it invariably present in a continuous zone. Infection does not generally occur once for all, but the hyphae from the soil infect the roots in several places and if the fungal zone be of several cells thickness it is frequently seen as patches in transverse section. Nor, as a rule, are all the roots of an orchid infected. Aerial roots particularly are free from fungus, the only exceptions being where the roots are applied to the soil and are without chlorophyll. Such a case is shown in Fig. 15. Aerial roots can sometimes be found in such a position with the exposed portion green: in these circumstances if infection occur the fungus is restricted in distribution to the portion of the root without chlorophyll. In addition to cells containing chlorophyll those containing tannin, mucus, raphides and other crystals are never invaded by the fungus. Lateral roots are more frequently infected than main roots and in those genera with numerous roots (*Orchis*, *Ophrys*) according to Stahl only one out of three of the roots arising from the rhizome have fungus present in their cortex. Moreover, certain genera such as *Listera* and *Epipactis*, which have their chlorophyll particularly developed, seem to be irregularly infected, whereas plants poor in chlorophyll, e.g. *Limodorum* and *Corallorhiza*, are well fungussed. All

* Janse has shown that in *Lecanorchis javanica* the infecting hyphae are sometimes united into a mycelial ribbon.

orchids so far investigated possess mycorrhiza, with the single exception of the saprophytic *Wullschlaegelia aphylla**. Large numbers both of native and exotic species have been studied—Wahrlich†, for example, examined over 500 of the latter cultivated at Moscow.

Since the earliest workers, e.g. Reissek, it has been known that in some cells at least the fungus becomes changed from its original thread-like structure into glary yellow amorphous masses. In fact, it was owing to this phenomenon that the fungal nature of the cell infections of these roots was not at first generally realised. Wahrlich paid special attention to the changes which took place, and most investigators of orchid roots since then have taken note of them. Magnus‡ working with *Neottia* in which the alterations are well marked gave a clear description of the metamorphosis. He distinguished two main types of infected cells and held that there were no transitional stages. In the one type which he calls "digesting cells" (Verdauungszellen) the fungus always degenerates; in the other type, the "host cells" (Pilzwirthszellen) the fungus remains alive in the cells which lodge it and is thus able to hibernate. Magnus states that *Neottia* shows a more or less definite arrangement of these two types of cells, the digesting cells forming an outer and an inner and the host cells the middle layer. Such a regular arrangement is not usual in orchids—even in *Neottia* it is doubtful—and host cells are absent in certain native genera, such as *Goodyera*, and in most tropical forms. Bernard and Burgeff have also studied the question of the fungus digestion—the former mainly in seedlings, the latter principally in the root of *Platanthera chlorantha*. Before a hypha enters a host cell the nucleus of the latter increases in size. This action at a distance is also seen in the fact that starch disappears from the cells. The nucleus in the neighbourhood of the hypha becomes hypertrophied, often becomes modified in form and has increased attraction for stains. Where mycelial influence is great the nucleus becomes amoeboid and sometimes disintegrates: this would seem to indicate a parasitic action on the part of the fungus. The digesting cells are clearly recognisable by the degenerating mass which more than half fills the cells. The increase in the size of the nucleus is also a character as it becomes about four times its original diameter, i.e. roughly sixty times the

* Further investigation is needed on this plant. MacDougal first recorded that *Cephalanthera oregana* was free from fungus, but later found a somewhat sparse and intermittent infection.

† W. K. Wahrlich, Beiträge zur Kenntnis der Orchideenwurzelpilze. Bot. Zeit. XLIV, pp. 481, 497 (1886).

‡ W. Magnus, Studien an der endotrophen Mycorrhiza von *Neottia Nidus-avis* L. Jahr. f. wissensch. Bot. XXXV, pp. 205–272 (1800).

volume. The nuclei become amoeboid and put out pseudopodia which serve to attack the hyphae. The hyphae only stain slightly: they increase in diameter up to about double and also in length. The development in some cases is so great that the cell is quite filled with the thick mycelial mass and the nucleus is crumpled by the hyphae. Enclosed by the pseudopodia the latter gradually lose their outline until frequently they cannot be distinguished from protoplasmic trabeculae. The victorious nucleus then assumes a round form and normal volume and reconstitutes its chromatin network. The endophyte is reduced to an amorphous yellowish clump with indistinct contour, and is absolutely devoid of life: it is surrounded by a cellulose membrane. It would seem that as the root ages the clumps finally disappear. After the formation of the clump starch often reappears in the cell. Burgeff states that the fungus in the host cells can re-attack digesting cells when similar stages are again gone through. We shall return to the question of digestion when we consider the seedling.

Germination of Seeds.

The difficulty in germinating the seeds of orchids is one which has been known for a considerable number of years. In fact, it was not until 1804 that any orchid seedlings were described, when R. A. Salisbury figured those of *Orchis Morio* and *Limodorum verecundum*. Later, many botanists such as Link, Irmisch, Beer, etc., added to our information concerning the stages of development. Orchid growers evolved the method of sowing seeds on the soil containing the parent plant*, and it was in this manner, or some modification of it, that most of the hybrids known in horticulture were raised. The facts known, i.e., the difficulty in germinating seeds unless placed on orchid soil and the presence of fungi in the roots, led many to suspect that the fungus was concerned in some way with the success or failure of germination.

We have mentioned that when Reissek recognised the fungal nature of the cell inclusions, he attempted to isolate them. This attempt, long before the days of bacteriological technique, was bound to end in failure and the fungus he isolated was a species of *Fusarium*, a genus which has been time and again proclaimed as the consort of the orchid root. (The genus *Nectria* also has often been assumed to be the endophyte.) It is to Noël Bernard that we are indebted for our chief knowledge of the facts of orchid germination. This brilliant young French investigator began his studies on mycorrhiza in 1899, and they extended until his death in 1911. His first investigation was on the germina-

* I believe Dominy of Messrs Veitch and Sons introduced this practice.

tion of *Neottia*. In 1902 in his thesis "Étude sur la tubérisation" he mentions that orchid seeds can germinate only in the presence of the root fungus and that the seedling is infected from its earliest stages. Realising the importance of this fact he turned his attention to investigating it thoroughly and following the various ramifications of the subject. Bernard's great work, "L'évolution dans la symbiose. Les Orchidées et leurs Champignons commensaux," appeared in 1909. In the same year a comprehensive work by Burgeff was published entitled "Die Wurzelpilze der Orchideen." Both these investigators succeeded in isolating the fungus from the orchid root and growing it on nutrient media. Orchid seeds germinated without difficulty on having the appropriate fungus supplied to them. In describing the course of events full use has been made of the work of Bernard and Burgeff, this being supplemented by observations made by the late Mr J. Charlesworth and the writer.

Joseph Charlesworth (1851–1920).

It will probably not be considered out of place here if I venture upon a few remarks concerning my friend the late Mr Joseph Charlesworth. In the year 1913 I was invited to Haywards Heath to see his results in raising seedlings by what he styled the "pure culture method." He had succeeded in eliminating many sources of error and had achieved remarkable and consistent results in raising *Odontoglossum* and its allies by sowing seeds on nutrient media in which the appropriate fungus was growing. The probability that the mycorrhizal fungus in some way affected the germination of orchid seeds had influenced him for many years and he had earned his great reputation as a hybridist by his success in raising hybrids by modifications of the methods in common use. In an account of a visit to his establishment in 1906 it was written "Here is a veritable seedling land, thousands and thousands of them," and in 1909 "The raising of *Odontoglossum* and allied genera has become a very important business, and there are thousands of seedlings in existence. Messrs Charlesworth are reducing it to a system." It was to one so successful by the older methods that Bernard's work made such a strong appeal, and he eventually decided to adopt the system. His culture flasks were sufficient testimony to the success of the laboratory method when placed upon a commercial scale. One was not prepared to find, however, that at the same time he had, after the age of sixty, become so embued with the new spirit as to have purchased microscopes, microtomes, ovens, stains, books, etc., and become proficient in microscopic technique. (The photomicrographs illustrating this paper are all taken from his preparations.) Naturally

he did not restrict his newly acquired activities to studying orchids, but the main part of his laboratory work dealt with them, and he was especially interested in the seed from its first formation and in the relations between fungus and seed in germination. The whole of the slides were generously placed at my disposal. We, however, drew up a scheme of collaboration and mapped out a series of investigations, which unfortunately had to be discontinued owing directly and indirectly to the war. When, in 1920, we were both again free to resume the work he was a sick man and beyond application to research.

I should wish to repeat here for the benefit of those orchid lovers who knew so well one part of his accomplishments that the other part was equally good. The fact that he should commence laboratory work at such a late age is as surprising as is the success which he attained practically unaided. To a botanist trained in the schools many of his expressions appeared whimsical, but when he termed the small cells at the distal end of an *Odontoglossum* seed the "soul of the plant," it was as a result of finding that it was there eventually that both stem and root were laid down—and he had a happy knack of coining such expressions and, one may add, a certain persistency in using them. If his early days had been spent in acquiring a knowledge of academic botany rather than in connection with his father's wool business, there can be no doubt that the name of Joseph Charlesworth would have been writ large in the annals of British science. As the firm of Messrs Charlesworth are carrying on the traditions of their late chief, it may be possible at some future date to complete and put on record certain of the investigations; and it is hoped it may be possible to carry out the original plan in which his knowledge of orchid culture would have played an essential part.

Orchid Fungus.

Bernard in his first attempts to isolate the fungus from orchid roots obtained a species of *Fusarium*. When, however, he succeeded in extracting the right fungus he established a criterion which enables one to settle without doubt whether the true fungus has been isolated, viz. that the endophyte is able to bring about the germination of the seed.

The fungus, when living within the cells of the plant, shows no characters which give a clue to its systematic position, but when it is grown on nutrient media it shows additional stages of development which are characteristic.

When extracted from the root and placed in a culture medium the fungus always appears to behave in the same way. The fungus spreads over the surface by the apical growth of its

septate filaments. Meanwhile lateral branches arise and anastomoses take place between the hyphae. Later, balls of hyphae appear here and there in the culture and on the sides of the tube or flask containing them, usually some distance from the ends of the hyphae. These balls are very similar to those which appear in the cells of the root, being formed by the rolling up of the ends of young growing filaments, and often becoming very compact. When seen in the host cells this method of growth suggests adaptation to the needs of the special environment, and its presence in cultures might lead to the supposition that the character is so impressed upon the fungus that it also shows it when living free. The character is, however, not rare in the group in which we must classify this fungus.

As the mycelium becomes older shorter filaments arise with very short and swollen segments, which are apparently rich in food reserve. (It was this appearance that caused Bernard to place the fungus in the genus *Oospora* when he first studied it.) These filaments ramify abundantly and in certain forms anastomose amongst themselves and give rise to yellow or brown sclerotia* (Figs. 4 and 5), small spherical bodies formed of intertwined and massed hyphae. These structures are capable of withstanding drought and other inclement conditions and are remarkably tenacious of life. Bernard has pointed out that these swollen filaments are very like those which occur in *Rhizoctonia violacea* Tul.† which is common on potatoes, lucerne and other crops, where it forms small, blackish, irregular sclerotia, and he considers that the orchid fungi fall into the same genus. He classed the fungi obtained from about twenty orchids as three species, *Rhizoctonia repens*, *R. mucoroides* and *R. lanuginosa*. The first, which was by far the most commonly isolated (*Laelia*, *Laelio-Cattleya*, *Spiranthes*, *Paphiopedilum*, *Cymbidium*, *Aerides*, *Bletilla*, *Coelogyne*), does not form sclerotia. *R. mucoroides* was found in *Phalaenopsis* and *Vanda*, and *R. lanuginosa* in *Odontoglossum* (Figs. 4 and 5). Burgeff, unaware of Bernard's latest results, proposed a new genus *Orcheomyces* for the reception of the orchid fungi. He fully describes fifteen species, naming them after the orchid from which he obtained them and mentions another fourteen by name: he divides them into five main groups.

A discussion of the different systematic interpretations given by Bernard and Burgeff would be out of place here and for convenience the more generally adopted name *Rhizoctonia* will

* Sclerotia are known in all groups of fungi, often reaching considerable dimensions, e.g. the size of a man's head in *Polyporus Mylittae* (the "black fellows' bread" of Australia).

† *Corticium vagum* B. and Br. var. *Solani* Burt.

be used. The diversity in the number of species is simply a case of the usual "lumping" and "splitting." Bernard found in his experiments that fungi obtained from different sources, but to which he gave the same specific names, varied somewhat in their behaviour, and it is quite probable that these physiological distinctions are related to slight morphological differences. Bernard later recognised certain of Burgeff's species as falling within his, e.g. *Orcheomyces Sambucinae, O. mascula, O. insignis* and *O. Luddigi* were regarded by him as *Rhizoctonia repens*—but he apparently took into account merely the gross characters of growth.

The endophytic fungus is able to ferment cellulose, which accounts for its ability to penetrate cell walls. Burgeff made a study of the physiological characters of the species he isolated. He found that they were able to absorb carbohydrates in the form of sugars, these being in all cases transformed by a diastase-invertase in some species, maltase in others. Having regard to the prevalent ideas as to the function of mycorrhizal fungi it is of particular interest to note that these forms are apparently unable to fix free nitrogen: the nitrogen of organic compounds, such as peptone, can be made use of as a source of nitrogen: ammonium compounds are better assimilated than nitrates. By growing cultures in the dark and in an atmosphere devoid of carbon-dioxide he established the fact that the carbon compounds of the soil can suffice as a source of carbon.

Bernard in his experiments found that the fungi if grown in culture gradually became inactive. Cultures two years old were quite unable to bring about germination. Burgeff, on the other hand, found that his cultures after twenty-six and twenty-eight months retained their power. In connection with this point a culture of a root fungus which had been regularly cultivated for at least eight years, though not used during that time for germination, was recently tried. A very feeble germination occurred in certain of the tubes. As the activity of the fungus when it was first isolated is not known, it is impossible to say whether there is any decrease in intensity, though this is probable. The gradual attenuation with final loss of activity noted by Bernard may be a consequence of "staling" through too infrequent renewal of cultures. He found that the intensity of an attenuated form can be increased by extracting it from a plant which it had been successful in germinating.

Germination of Seeds—*continued*.

The seeds of orchids are very small, the embryo being frequently only just visible to the naked eye*. They possess a

* The embryo in Fig. 2 is approximately 200μ, i.e. c. $\frac{1}{125}$ inch.

single integument which is in the form of a characteristic network (Fig. 2) which varies somewhat in shape and structure in the different genera. On sectioning the seed (Fig. 3), or on viewing when stained and mounted whole, there is seen to be no differentiation into cotyledon, stem, radicle, as is almost universal in flowering plants*. It appears to be most usual for the cells at the suspensor end of the seed to be somewhat larger than at the upper end (Fig. 3), though this is not always the case (*Cypripedium*). Sometimes the suspensor cells are permanent (*Cattleya*)—the suspensor is the stalk by which the developing seed is attached and nourished—at other times they disappear before the seed is matured (*Phalaenopsis*). Seeds taken from the capsule under sterile conditions and sown on ordinary substrata where no fungus is present do not as a rule develop. Generally they merely swell and become green (*Odontoglossum*) though sometimes even this does not happen (*Epidendrum*); in other cases they may form stomata and the rudiments of hairs (*Cattleya*). The only case so far known in which any considerable development can take place under these conditions is *Bletilla hyacinthina* where Bernard found that thin slender seedlings developed with distinct leaves. The food reserve of orchid seeds is most frequently oil, part of which becomes transformed into starch. The reserve food comes to its end just as the seed commences to become green. This is usually after three or four months, during which time very little, if any, nutriment can be obtained from the substratum, as absorbing hairs are lacking. If no fungus infection take place then, the seedling dies. It is somewhat surprising that after the production of chlorophyll death should occur rather than autonomous growth by aid of photosynthesis: the seedling appears to form chlorophyll as a sort of last despairing effort.

If, however, the appropriate fungus (i.e. the fungus from the root of the parent or some closely allied plant) be added now at the latest, an extraordinary change takes place. The fungus seems to give an impetus to development.

In the culture flasks it is only in prearranged experiment that infection takes place at such a late stage. The fungus enters the seed usually within a few days. The course of events may be made out from the photomicrographs, which are taken from different genera in order to show the general similarity in the phenomena. Entry takes place at the suspensor end of the seed between the suspensor cells themselves, if such be retained. The cell walls here are unmodified, though the general surface of the

* *Bletilla hyacinthina* shows a rudimentary cotyledon according to Bernard. Treub has indicated a cotyledon in *Sobralia macrantha*, and Pfitzer records a green embryo with a differentiated cotyledon in *Platyclinis glumacea*.

seed is slightly cuticularized. As we have seen, the cells at the suspensor end of the seed are generally larger, and it is into these that the fungus passes (Figs. 3, 6, 7, 8). The cells are invaded by degrees, the hyphae becoming twisted into a ball in each cell before passing on to the next. Almost immediately the smaller cells at the opposite end of the seed undergo division. It is here that the meristem of the stem is laid down. The meristematic cells in orchids are never entered by the fungus: the only cells capable of division which ever harbour the endophyte appear to be those of the seed where it first enters. Eventually the developing seedling takes on a swollen shape most frequently more or less turbinate (Figs. 9, 10).

Bernard uses the term "protocorm" for this swollen tubercle and regards it as of theoretical importance, as it simulates the protocorms of Lycopods and the colourless underground prothalli of Adder's Tongues, etc. It is of interest to remark that a similar structure, also associated with fungi, occurs in the primitive fossil plant *Hornea* from the Devonian. The fungus remains restricted to the larger cells and follows in the wake of their division. The epidermal layer is free from infection. Meanwhile the rapid division taking place in the smaller cells at the anterior end of the seed gives rise to the young stem apex and the first leaf (cotyledon). About the time this young leaf becomes visible to the naked eye the cell-division has become extended along the axis and the beginning of the central stele is seen (Fig. 10). In this manner the young root is formed and begins to absorb its way through the tissues of the protocorm (Fig. 11). Finally it passes out into the soil (Fig. 12). In no orchid studied in the present series (*Odontoglossum, Oncidium, Cattleya, Cymbidium, Vanda, Cypripedium,* etc.) does the developing root when passing through the tissues enter the fungal zone nor do the hyphae extend into the root. In fact there is often a suggestion of a delimiting membrane separating the two areas (cf. Fig. 12). Thus when the root enters the soil it is absolutely free from infection; in none of the usually cultivated orchids does the root receive fungus from the swollen protocorm. Infection takes place from the soil most frequently when the root is about a quarter of an inch in length, the hyphae entering by the root hairs a little behind the region of greatest growth. This throwing off of the fungus, as it were, is repeated in orchids with tubers which do not retain their roots: the tuber is not infected and the new roots receive their fungus from the soil. In fact, in orchids so far studied it is only in the saprophytic *Neottia* that constant infection obtains. Here infection progresses gradually from the widely infected protocorm into the body of the plant, gains the rhizome and infects the successive

roots. The region of infection is thus perfectly continuous throughout the plant from the tip of the protocorm to the base of the inflorescence: as Bernard remarks, according to the evidence the whole of the mycelium harboured by a *Neottia* has for its single origin the mycelial filament which first penetrates the embryo*.

The question arises as to whether root infection *per se* is obligate in orchids with abundant chlorophyll or whether it is a necessary evil. If the latter, one would expect the fungus to be lodged in the roots, though restricted in distribution. As stated above, all the cells entered seem to act as digestive cells in cultivated orchids. Is such digestion a device for protection or for nutrition?

What has been happening to the fungus during these stages? The course of events was first followed by Bernard. As we have seen, the fungus enters at the suspensor end of the seed by the cells of the suspensor near the point of attachment (*Odontoglossum*) or by the cells of the pole of the embryo where the suspensor is attached (*Vanda*). There appears to be an attraction, though feeble, towards the place of entry. The first filament entering the seed apparently excludes all others, though it may be of an attenuated form and unable itself to bring about germination. Bernard compared this with vaccination: the infection immunizes the seed. In successful germinations the fungus, after seed entry, follows the development of the cells forming mycelial balls in all the posterior portion of the seedling. According to Bernard, when the fungus reaches the cells bordering on the meristematic region digestion takes place. This is regarded as being analogous to phagocytosis such as occurs in animals where the white corpuscles of the blood attack, engulf and digest any invading micro-organisms: the cells in which the digestion takes place are the phagocytes.

In general these may be regarded as definite cells often recognisable, even before infection on account of their nucleus sometimes becoming lobed. The balling of the fungus in the cells is compared with agglutination, and the manner in which this occurs only in cells of the developing seedling which have achieved their growth is compared with cases of mortal infection where the balling is abandoned sooner or later and the fungus grows on in every direction and invades all the tissues indifferently.

* The association can be even more close under certain conditions. Flower scapes are frequently unable to pierce the humus covering them and the flowers and seeds develop underground, sometimes beneath the root-tufts which produce them. Mycelium apparently from the rhizome of the plant passes up the central cavity of the stem and infects the seeds in the subterranean fruits which are thus able to germinate.

Digestion eventually takes place in all the more deeply lying cells, while the external layers act as host cells. The fungus can pass out of the protocorm by way of the hairs present on its surface.

This application of the theory of phagocytosis is a most attractive one. Gallaud* first suggested the similarity of the function of the digestive cells and that of phagocytes, but it is to Bernard that we owe the working out in detail†. Much investigation on the germinating seed is still needed. Bernard's account of the distribution of the phagocytes is not satisfactory. As the photomicrographs (Figs. 10, 12, 13) show it is not unusual for all the infected cells of the protocorm to be able to digest the fungus eventually.

Germination without Fungus.

How far is it possible to replace the fungus by artificial conditions? Bernard concluded from a consideration of the way in which the endophyte can act at a distance, i.e. bring about changes in cells to which it has not access, that there is a general modification of the physico-chemical properties of the sap which can reach all the tissues. He tried the effect of solutions of salep and saccharose of increasing concentrations on seeds of *Bletilla*, *Cattleya* and *Laelia*. In *Bletilla* where, as we have seen, germination takes place with the formation of slender seedlings in the absence of fungi, in high concentrations most of the seedlings showed thickened protocorms and short internodes comparable with fungus infected individuals. The seeds of *Cattleya* and *Laelia* at low concentrations swell and become green. With higher concentrations development is always much slower and more irregular than with fungi, but one can obtain seedlings of quite normal appearance. As the concentrations increase the development is increasingly better, but more irregular: but there is an upper limit beyond which there is no germination.

Thus it appears that augmentation of the culture medium can, in certain cases, supply the place of fungus action. In fact Bernard states that in the condition of his experiments it was more certain and easier to germinate certain seeds by the action of concentrated solutions than to have recourse to fungal infection. Germination was slow, but very regular, the protocorms had a normal appearance and the seedlings when fairly developed could be transplanted. Experiments showed that *Rhizoctonia* was able to increase the concentration of the solutions in which

* F. Gallaud, Études sur les mycorrhizes endotrophes. Rev. Gén. Bot. XVII, pp. 5 et passim (1905).

† Bernard (1911) also showed that the bulbs of *Loroglossum* contain a diffusible substance which has a fungicidal effect on *Rhizoctonia*.

it grew and Bernard considered it probable that it acts similarly in orchid tissues and increases the degree of concentration of the sap. This problem of autonomous germination recalls to mind that of parthenogenesis—the development of an ovum without the intervention of a spermatozoon. The egg possesses all the substances necessary for activation: the spermatozoon is an inciting cause of these reactions within the egg system on which development depends. Parthenogenesis occurs naturally in certain groups, but it has been brought about experimentally in numerous cases where fertilization normally obtains*, †. Apparently the first successful attempt was made by Tichomiroff in 1886, who stimulated the unfertilized ova of the silk moth to development by rubbing them between two pieces of cloth. Various methods have since been used such as treatment with fatty acids, certain salts such as barium chloride, lipoid solvents such as chloroform, hypertonic and hypotonic solutions, etc.‡.

Another significant similarity is that artificially activated eggs always show a marked slowness in their rate of development, even with the best methods, as compared with the fertilized eggs. This suggests, according to Lillie, some factor that has not yet been successfully imitated in any artificial way. Is it possible that in both cases accessory food factors (vitamines) may play a part? In considering the case of seeds it might be pointed out that there are many instances of peculiar germination known in other phyla. Pinoy§ showed that spores of Myxomycetes such as *Chondrioderma difforme* do not germinate unless bacteria are present. Ferguson|| discovered that the only way in which she could germinate the spores of the common mushroom effectively was by having a little mycelium of the fungus present in the cultures, and Servettaz¶ found that a species of *Oospora* activated the growth of the moss *Phascum*

* F. R. Lillie, Problems of Fertilization. Univ. of Chicago Science Series (1919).

† Y. Delage and M. Goldsmith, La parthénogénèse naturelle et expérimentale. Paris (1903).

‡ The only case in which parthenogenesis has been induced in the entire vertebrate phylum is in the frog, where Bataillon in 1910, after years of vain attempts, finally succeeded by the exceedingly simple method of pricking the eggs with a fine needle. It is necessary that blood or tissue extract should be carried into the egg by the needle. This method has been abundantly confirmed and tadpoles so obtained have been reared to maturity by Loeb and Bancroft.

§ E. Pinoy, Rôle de bactéries dans le développement de certains Myxomycètes. Ann. Inst. Pasteur, XXI, p. 632 (1907).

|| M. C. Ferguson, A preliminary study of the germination of the spores of *Agaricus campestris* and other Basidiomycetous fungi. U.S. Dept. Agric. Bureau of Plant Industry, Bull. No. 16 (1902).

¶ C. Servettaz, Recherches expérimentales sur le développement et la nutrition des mousses en milieux stérilisés. Ann. Sci. Nat. 9 sér. XVII, pp. 111–224 (1913).

cuspidatum to a remarkable degree, though the favourable action was of short duration in the conditions of his experiments.

Gastrodia.

An unusual and interesting type of mycorrhiza occurs in *Gastrodia elata**, a non-chlorophyllous orchid widely spread throughout Japan, where it occurs mostly in woods under *Quercus serrata* and *Q. glandulifera*. The full-grown flowering tuber is oblong and slightly curved, attaining almost without exception a length of 10–17 cm. This tuberous rhizome is the whole vegetative part of the plant and consists essentially of parenchymatous cells. Multiplication usually takes place by the tuber. It produces long rhizomes from its apex or node, upon which stalked off-sets are developed. At the end of autumn the mother body and the pedicel of the off-set undergo degeneration, so that the daughter tubercles are set free. Unless the mother tuber has been infected with the necessary fungus the off-sets decrease in size with each successive generation, until they become so much reduced and deficient in food materials that they are incapable of further multiplication. The fungus necessary for proper development is not a microscopic mould as in the other orchids studied, but *Armillaria mellea*, the well-known "honey fungus." This toadstool is extremely common in our woods where it is a most destructive parasite, "indeed more trees die, in Europe at any rate, from attack by this fungus than through any other parasitic agent†." The fructifications are found generally on or near stumps. If the earth beneath the toadstool be dug up it will be found to contain one or more black strands, resembling bootlaces, which are attached to the base of the stem. These rhizomorphs, as they are called, consist of densely compacted fungus mycelium. Further, the mycelium in the wood of the tree itself is first felted and grows up through the cambium to a considerable height: when the tree is dead and the bark has become loosened the mycelium is transformed into a tangled mass of flattened rhizomorphs. Early mycologists considered that they were here dealing with three different species of fungus—the toadstool (*Agaricus melleus*), the rhizomorph under the bark (*Rhizomorpha subcorticalis*) and the rhizomorph in the ground (*Rhizomorpha subterranea*).

It is with the subterranean rhizomorph that we are here concerned. It forms a cylindrical, smooth, black strand, usually 1 to 1·5 mm. in thickness. Its peripheral portion, the so-called cortex, consists of compact, pseudoparenchymatous, brownish

* S. Kusano, *Gastrodia elata* and its symbiotic association with *Armillaria mellea*. Journ. Coll. Agric. Imp. Univ. Tokyo, IV, pp. 1–66 (1911).

† W. E. Hiley, The fungal diseases of the common larch. Oxford (1919).

mycelium with a comparatively thick wall. The middle layer is composed of a bundle of large thin-walled mycelia with numerous septa. The inner cavity of the strand is traversed by a loose bundle of very fine longitudinal hyphae rich in protoplasmic contents.

When the tuber of *Gastrodia* is attacked by the rhizomorph, infection is effected by a sucker-like branch of the strand which penetrates the cortical cell layers, partly compressing the underlying cells and partly dissolving their walls. This mode of infection is, of course, quite different from the ordinary endophytic mycorrhizal type where infection is effected as a rule by a single hypha (cf. p. 31). It very much resembles the manner in which the parasitic *Cuscuta* attacks its hosts, the rhizomorph creeping over the surface of the tuber and giving off the infection branches at intervals. On entering the tuber the hyphae of the various portions of the strand essentially retain their structure. The infected area of the tuber may be divided into three regions, according to the structure of the cells and the nature of the hyphae contained within them. The external region is composed of two or three layers of cells which contain a densely entangled mass of comparatively thick-walled hyphae; the middle region is similarly composed, except that the hyphae are generally thin-walled and of various breadths and often arranged as a pseudoparenchyma; the innermost region has large cells each containing a few, slender, slightly curved hyphae. The three regions correspond to the zones in the rhizomorph. The hyphae of each region show characteristic alterations. They are permanent in the first region; in the second they undergo self-disorganization; while in the third they are mostly consumed by the cells of the host. The mode of development of the fungus in the middle region simulates the ordinary clumping seen in most orchids, but the course of events is different in that the protoplast is consumed by the hyphae before their collapse takes place. The destruction of the protoplast shows the parasitic properties of the hyphae. The cells of the inner regions are apparently metabolic centres of the orchid where the food materials are elaborated. The nucleus and cytoplasm undergo remarkable alterations, and secondary products appear indicating considerable activities. After the disappearance of the hyphae the nucleus resumes its original form and structure, while the cytoplasm again becomes fibrous and vacuolate. Starch grains disappear from all the mycorrhizal cells, to reappear in the inner region with the cessation of metabolic activity.

The association of tuber and rhizomorph takes place quite occasionally. If a tuber forms mycorrhiza it can give rise to a full grown off-set which remains dormant during the winter and

develops the inflorescence axis in the following year: otherwise no flowers are produced.

So far no results have been published as to the germination of the seeds of *Gastrodia*. One would expect that fungal infection is necessary for seedling development, but whether the fungus is a form like *Rhizoctonia* or whether there is some adaptation by which *Armillaria* becomes operative remains to be seen. In either case the facts will be of the greatest theoretical interest.

The course of events in *Gastrodia* gives some support to the idea that the relation of fungus and orchid is primarily one of parasitism on the part of the former. At times the rhizomorph attacks tubers and destroys them in a manner similar to that in which it treats potato tubers. Usually, however, the fungus is kept well under control and its hyphae prevented from spreading beyond their apportioned region—and even so being absorbed by the orchid cells. It is difficult to see what benefit the fungus can gain under these conditions. The subterranean strands are apparently unable to obtain nutriment from the soil, their function in the usual life of the fungus being that of "runners." It would seem that *Gastrodia* has turned the attack of these into one of service for transmitting nutriment from the oak stumps to which the fungus is attached, for its own benefit: a colourless saprophyte unable to grow or to flower without the aid of one of the most destructive parasites known!

Number of Seeds and Distribution of Fungus.

When one sees the dense masses of seedlings thriving in the culture flasks one contemplates as to the course of events under natural conditions. The enormous numbers of seeds which are usually produced in the capsules of orchids must have struck the most casual observer. "Not that such profusion is anything to boast of; for the production of an almost infinite number of seeds or eggs, is undoubtedly a sign of lowness of organisation. That a plant, not being an annual, should escape extinction, chiefly by the production of a vast number of seeds or seedlings, shows a poverty of contrivance, or a want of some fitting protection against other dangers." Darwin* estimated that in *Cephalanthera grandiflora* a single capsule contained 6020 seeds and that, therefore, a plant with the usual four capsules would have 24,080 seeds. Similarly *Orchis maculata* had 6200 seeds in a single capsule, and thus a plant having the not unusual number of thirty capsules would produce 186,000 seeds: "As this orchid is perennial, and cannot in most places be increasing, one seed alone of this large number yields a mature plant once

* C. Darwin, Fertilisation of Orchids (1862).

in every few years." In order to retain the number of individuals of a species stationary it is only necessary that one mature plant should be produced during the period of growth of the parent—if more occur the species will tend to oust out all other species. "Linnaeus has calculated that if an annual plant produced only two seeds—and there is no plant so unproductive as this—and their seedlings next year produced two, and so on, then in twenty years there would be a million plants....It would suffice to keep up the full number of a tree, which lived on an average for a thousand years, if a single seed were produced once in a thousand years, supposing that this seed were never destroyed, and could be ensured to germinate in a fitting place*." To give an idea of what the above figures for *Orchis maculata* really mean Darwin worked out the possible rate of increase. "An acre of land would hold 174,240 plants, each having a space of six inches square, and this would be just sufficient for their growth; so that, making the fair allowance of 400 bad seeds in each capsule, an acre would be thickly clothed by the progeny of a single plant. At the same rate of increase, the grandchildren would cover a space slightly exceeding the Isle of Anglesea; and the great grandchildren of a single plant would nearly (in the rate of 47 to 50) clothe with a uniform green carpet the entire surface of the land throughout the globe"—and as *O. maculata* is perennial, the parent plant would still be alive!

But even these numbers in our native orchids are much exceeded by those of tropical species. Scott estimated that a capsule of *Acropera* contains 371,250 seeds and, judging from the number of flowers borne by the plant, the total number of seeds for an individual would be 74,000,000: Charlesworth estimated 825,000 seeds for a single capsule of *Cymbidium Traceyanum*: Muller 1,756,440 seeds for a single capsule of *Maxillaria*. It appears to be a general biological rule that where the conditions of successful germination are difficult of attainment a prolific number of seeds (or spores) are produced and, *vice versa*, where the requirements are not of a specialized nature, a smaller number occur.

In the case of orchids it seems not unlikely that the enormous seed production is in some way related to the fungus question. Their small size, their lightness, their net-work integument and the presence in some genera of elaters ensure their effective dissemination. But unless the necessary fungus be to hand no germination occurs—the seed may develop to a certain extent, but it does not produce roots unless the appropriate fungus enters its cells.

So far, however, we know nothing of the distribution of these

* C. Darwin, Origin of Species (1859).

fungi in nature except so far as they occur associated with rooted orchid plants. Probably most people are aware that fungi of all kinds are present in the soil, but few realize in what enormous numbers they occur and the manner in which some are restricted to the soil. Hagem* calculated that in a gram of soil from a potato field, 350 spores of *Rhizopus stolonifer* and 250 each of *Mucor sphaerosporus, M. nodosus, Absidia cylindrospora* and *Zygorhynchus Moelleri* were present; and these numbers are much exceeded by *Penicillium* (90–95 per cent. of spores in uncultivated soil according to Sopp†) and other Hyphomycetes. Traaen‡ calculated that from 10,000 to 120,000 spores of *Geomyces vulgaris* and from 1000 to 20,000 spores of *Humicola fuscoatra* occur in a gram of soil. Much work has been done recently on the biological activities of such fungi, attention being paid chiefly to cellulose destruction and the possibility of nitrogen fixation. It is extremely probable that certain of the forms isolated are capable of acting as mycorrhizal fungi, though none have apparently been recognised as such. Further it is possible to isolate *Rhizoctonia* from the soil in the immediate neighbourhood of orchid plants growing wild (as also from the soil of pots containing cultivated orchids): but notwithstanding the large number of species of soil fungi isolated it does not appear to have been found, or at least recognised, by any investigator. We are thus lacking in data as to the distribution of orchid fungi in the soil. Since, however, Bernard isolated *Rhizoctonia repens* from many European orchids and showed it to be the commonest endophyte amongst cultivated species, it must be of world-wide distribution, since in order to account for the distribution of the orchids it is necessary to assume that this particular fungus must occur practically wherever orchids grow.

ERICACEAE.

A family of plants which is usually linked with orchids as showing the same constancy of fungal infection is the Ericaceae. Frank early realized that the relation between the fungus and flowering plant in these two families is a particularly close one. In certain ericaceous plants he remarked on the absence of root-hairs, the absence of, or reduction in, the amount of cortical tissues, the reduction of the root-cap, and the masses of fungus mycelium in the enlarged cells of the epidermal layer. Ternetz§

* O. Hagem, Untersuchungen über Norwegische Mucorineen II. Skrifter Vidensk.-Selsk. Christiania. I. Math.-Natur. Kl. No. 4 (1910).

† O. J. O. Sopp, Monographie der Pilzgruppe *Penicillium*. Idem, No. 11 (1912).

‡ A. E. Traaen, Untersuchungen über Bodenpilze aus Norwegen. Nyt Mag. Naturvidensk. LII. pp. 19–121 (1914).

§ C. Ternetz, Über die Assimilation des atmosphärischen Stickstoffes durch Pilze. Jahrb. f. wissensch. Bot. XLIV, pp. 353–408 (1907).

was successful in isolating the fungi from certain species and growing them in pure culture, constantly obtaining the same fungus from the same species of flowering plant. All the fungi belonged to the genus *Phoma**—one of the Fungi Imperfecti, but of a totally different group than is *Rhizoctonia*—and were apparently morphologically and physiologically distinct. She showed that infection of *Calluna* took place in the seedling and also found infection in a case of viviparous germination in *Andromeda*.

Rayner† working with *Calluna vulgaris* was able to show that the full development of the seedling was dependent upon the presence of the mycorrhizal fungus—there is here an "obligate symbiosis" of a type very similar to that in orchids. Finding that the sterile seedlings were unable to form a root-system she investigated the matter in the manner made classical by Bernard. The seed coats were found to become infected while the seeds are still in the ovary. Delicate branched hyphae are present in the cells of the ovary wall, in the tissue of the central column and in the funicles of the seeds. Branches of this mycelium grow across from the cells of the ovary wall to those of the seed-coats, extending from one seed to another. The fungus was isolated and grown in pure culture. It proved to be a pycnidial form similar in all respects to the genus *Phoma*. Sterile seeds sown on this develop normally, whereas in its absence the seedlings merely form a few reddish or chlorotic leaves, but no roots. Infection of the seedling root takes place at, or immediately after, it emerges and may begin at the tip by hyphae forcing their way between the cells of the apex, though more usually it occurs simultaneously at several points. The mycelium immediately becomes intercellular and infection spreads rapidly from cell to cell. Some hyphal branches grow out and infect fresh rootlets as they develop; others form a tangled skein of fine hyphae in the superficial cells. One of the most interesting points of the story is, however, that the fungus does not remain confined to the roots but infects the whole of the young seedling. In the subaerial parts the mycelium does not develop so extensively on the surface of the plant, nor do the hyphae become balled up in the superficial cells as in the roots, but are irregularly distributed in the tissues. In the mature plant likewise the fungus is not confined to the roots but is present in the tissues of the stem, leaf, flower and fruit. The hyphae can also be seen ramifying among the hairs or closely applied to the cuticle of

* *Phoma radicis-Oxycocci*, *P. radicis-Andromedae*, *P. radicis-Vaccinii*, *P. radicis-Tetralicis* and *P. radicis-Ericae*.

† M. C. Rayner, Obligate symbiosis in *Calluna vulgaris*. Ann. Bot. XXIX, pp. 97–133 (1915).

the epidermal cells: they show no preference for special points of entrance or egress, penetrating with equal ease the cuticularized cells of the epidermis or the base of a hair. The ovary—and later the young fruit—contains mycelium in all parts of the internal tissues. This mycelium infects the seed coats of the developing seeds. The embryo and endosperm of the resting seed are free from infection.

Thus, as in *Neottia*, we are dealing, except in the seed, with a dual organism. The type of association is, however, different from what obtains in the orchids so far studied, where no such distribution has been found—and an analogous constancy apparently only occurs in non-chlorophyllous genera. From the fact that Rayner has recorded the presence of ovarial infection in a number of Ericaceae—Rhododendroideae, Arbutoideae, Vaccinioideae and Ericoideae—it may be that the fungus is similarly distributed throughout the tissues of these plants, and presumably obligate symbiosis is to be inferred.

In no other case has the necessity of the presence of the mycorrhizal fungus for germination been proved. There can be hardly any doubt, however, that such a phenomenon is not restricted to two groups so widely separated as the Orchidaceae and the Ericaceae. What have these families in common? Apart from the similarity in habitat of certain species there seems to be nothing except the smallness of their seeds—and it is naturally to seed characters that one looks in this connection. As we have seen, the seeds of orchids are exceedingly small; reduction in most genera would appear to have reached its limit. In typical Ericaceae the seed is very small, rarely exceeding 2 mm. and often less than half this size. There is a richly developed endosperm in which a straight embryo is embedded one-half to two-thirds the length of the seed, always showing a root, an axis and two cotyledons more or less differentiated. It is also of interest to remark that such genera as *Kalmia* and *Ledum* have a net-work integument to the seed.

PYROLACEAE.

Allied to the Ericaceae is the family Pyrolaceae with the sub-families Pyroloideae and Monotropoideae. In families of flowering plants which show saprophytism and parasitism there usually occur green purely autophytic plants, with typical green leaves and numerous flowers; plants that are purely saprophytic or parasitic, with colourless scales and a reduced number of flowers; and all gradations between. Henderson* instances the

* M. W. Henderson, A comparative study of the structure and saprophytism of the Pyrolaceae and Monotropaceae with reference to their derivation from the Ericaceae. Contrib. Bot. Lab. Univ. Pennsylvania, v, pp. 42–109 (1919).

families Burmanniaceae, Orchidaceae, Gentianaceae and Ericaceae as examples of this. Regarding the Pyrolaceae as a saprophytic sub-family of the Ericaceae we can trace a relation between increasing saprophytism and a more intensive development of mycorrhiza. In the root-tip region we get an ascending series in the amount of fungus present from *Chimaphila umbellata* where the epidermal cells of some roots are without hyphae and other roots with hyphae, but not in every cell, to *C. maculata* with a greater number of the epidermal cells filled with hyphae; in *Pyrola rotundifolia* and *P. elliptica* all the cells are infected, and there is the beginning of intertwined hyphae round the root tip; then in *Monotropa Hypopitys* an increase in the width and extent of the sheaths and a division into two zones—an outer loosely woven mass of hyphae and an inner more compact one—and finally in *M. uniflora* a still greater width of the fungal sheath. In the least saprophytic species the epidermis soon dies off, carrying with it the fungal hyphae as in *Chimaphila* and *Pyrola*, whereas in *Monotropa*, especially *M. uniflora*, the epidermis is still living and filled with hyphae when the root is quite old.

Corresponding with this increase in saprophytism there is an increase in the number of seeds produced and a reduction in their size and structure. "The endosperm in the Pyrolaceae consists of relatively few large cells—the embryo of about twenty-five to thirty cells with no trace of cotyledons. In the Monotropaceae the number of endosperm cells is still less and the cells are larger, the embryo also is very small, composed of only nine or five cells." As these seeds also have their integument in the form of a net-work there is an exceedingly close superficial resemblance to those of orchids.

Comparing the members of the Pyrolaceae as a whole with the Ericaceae it would seem exceedingly probable that their seeds are even more dependent upon infection by the mycorrhizal fungus than are those of their chlorophyllous relatives. It will be interesting to learn at what stage infection takes place and whether or not a close approximation to the more advanced orchid type obtains. It is probable that the fungus will be found to be generally distributed in these plants as in *Calluna*.

Burmanniaceae and Gentianaceae.

The other two families in which mycorrhizas are typically developed are the Burmanniaceae and the Gentianaceae*—in

* "Most of the Orchideae are humus-plants, and it is noteworthy that dicotylous saprophytes, such as the Pyrolaceae, the gentianaceous *Voyria*, and others, show a reduction of the embryo like that of the Orchideae. In *Monotropa* the embryo has but nine cells. The germination of the seeds of these dicotylous saprophytes is unknown. It takes place only in the presence

fact Stahl considered that from this point of view the latter family are as important as the Orchidaceae. Moreover, in these families the seeds are small and numerous, with little reserve food material and no chlorophyll. Further there are the typical gradations from green plants to colourless saprophytes and correlated with this is an increase in number and decrease in size of the seeds, with a change in the embryo until we end in the most reduced examples with little differentiated or formless masses, and an increasing amount of fungus in the roots. The seeds of the saprophytic genera have a net-work integument and in appearance bear a very close resemblance to those of orchids. The Burmanniaceae are closely related to the Orchidaceae, and we should expect that showing so many characters in common there would also be a resemblance in the important one of obligate fungal infection for germination. In the Gentianaceae there are many isolated records of difficulties in obtaining seed germination in some of the genera, and it is common knowledge that many Gentians are difficult to raise from seed. It would seem extremely probable that in this family also the mycorrhizal fungus is necessary for seedling development.

Ceillier* has worked out in detail the relation between the presence of mycorrhiza and small seeds. In certain cases as in Juncaceae the seeds are small and little differentiated, but as they possess chlorophyll they are able to begin photosynthesis immediately on sowing. Small seeds with much reduced embryos also occur in parasitic forms such as *Cuscuta*, *Orobanche*, etc. No fungus is present in these genera, but apparently germination is not successful unless contact is made with the organs of the requisite host. It may be that the stimulus necessary in these cases is analogous to that requisite to bring about root formation in plants with obligate mycorrhizas.

Origin of Saprophytism.

What is the trend of evolution in plants of which the roots are normally infected with endophytic fungi? A general survey of families in which endotrophic mycorrhizas are typically developed shows that it is the rule for these families to have small seeds ill-adapted for successful germination. It has also been proved for orchids and for *Calluna* that the seeds need to be infected by the mycorrhizal fungus before the seedling can

of very special surroundings. Probably the fungi which are found in the roots in symbiosis are essential. The smallness of the seeds allows of a large number being formed, and thus the probability that one of the seeds at least will reach favourable conditions for germination is increased," Goebel, Organography of Plants, Part II, pp. 254 [1898] 1905.

* R. Ceillier, Recherches sur les facteurs de la répartition et sur le rôle des mycorhizes. Thèse, Paris (1912).

produce roots. Further it is in these families that typical saprophytic species occur (if we concede that the Pyrolaceae are saprophytic Ericaceae): in fact the presence of fungi in the roots of saprophytes is so common (the apparent exception being *Wullschlaegelia*), that MacDougal regards these seed-plants as being "saprophytic symbionts*." Without the necessary data it is doubly unsafe to theorise, but it suggests itself that in families adapted to a mycorrhizal habit there is a tendency for the seed to become dependent upon the fungus for successful germination, and there is a correspondingly greater production of seed. It has been customary to associate increasing saprophytism with the greater development of mycorrhizal fungus. May it not be rather that saprophytism has arisen by the mycorrhizal fungus taking over some of the functions necessary in germination and relieving the flowering plant of the need of excessive food production for the developing seed and thus of the necessity for carbon assimilation? (The great amount of fungus in the roots of saprophytes militates against the idea that the root may be simply a lodging-place for the fungus to be at hand for germination and of no use in nutrition.) We see in *Calluna* an almost perfect device for the infection of the seed, and the fungus is generally distributed. The most general infection so far found in orchids is in *Neottia*, which, as has been pointed out above, is most comparable with *Calluna*. But *Neottia* is saprophytic. In chlorophyllous orchids it almost looks as if when the necessary stimulus is given for seed germination precautions are taken to prevent general infection, the primary root even being free. In orchids digestion of the endophyte may also be a means of preventing general infection (though in *Neottia* this property can be easily recognised). Does such a general infection as we get in *Calluna* ultimately lead to saprophytism of the type seen in the Pyrolaceae? Are the events described above in the germination of certain orchids an effort to prevent general invasion and the "perfect symbiosis" of *Neottia*?

LOLIUM.

A case which recalls to mind that of mycorrhiza—especially having regard to recent discoveries—is that of the grass *Lolium*. The fact that the grains of *Lolium temulentum* contain a layer of fungal hyphae situated between the aleurone layer and the fruit and seed coat was first demonstrated by Vogl in 1898, and since then has been many times investigated in different species

* Johow (1889) places all the known saprophytic flowering plants in the six families Orchidaceae, Burmanniaceae, Triuridaceae, Piroleae, Monotropeae and Gentianaceae. (The Triuridaceae are a small family of tropical saprophytes with the two genera *Sciaphila* and *Triuris* and about forty species.)

of the genus. The latest worker is McLennan* who used *Lolium perenne* for her researches. The fungus is far more common in the genus than has hitherto been thought, and it is remarkably constant. Every seed examined (169 of *L. temulentum* and 115 of *L. perenne*) showed infection. The fungus is endophytic, occurring within the cells. It is present in the embryo sac at, or immediately after, fertilization: thus there is a material difference from what happens in orchids and *Calluna*. The fungus increases in quantity at the expense of the nucellus and the cells of the carpel wall. As the endosperm is formed the fungus is absorbed as a source of food supply for the developing embryo. The ovum is infected before any divisions have taken place in it.

The hyphae already in the very young embryo follow the development of the stem-apex and remain localised in their growth until germination takes place. The growth of the fungus keeps pace with that of the plant: the hyphae, however, are mainly restricted to the growing apex, but can be seen extending for a short distance down the stem. Even at this stage the intracellular nature of the fungus can be demonstrated. Some of the parenchymatous cells of the grass are invaded and used as a food supply by the hyphae. When the inflorescence is formed the fungus is especially abundant at the base of the carpels. The cells so affected do not increase in size, and are only to be distinguished from normal unaffected cells by their different staining properties. It is not till the ovule is well advanced that any great increase in the fungal partner takes place. The fungus has not yet been isolated†. It has been suggested that it is probably a degenerate member of the Ustilagineae (Smuts) or of the ergot type. The former would seem the more likely. Smuts attack grasses very generally and often it is the flower that is infected and later the seed, and thus the whole plant. On general grounds it would appear that the line of development to the stage found would be the gradual subjection of a parasitic fungus such as *Ustilago* rather than the further development of a typical mycorrhiza. An examination of *Lolium* roots shows that no typical endophytic fungus is present—in fact these are peculiarly absent in the Gramineae, though recorded by Schlicht for *Holcus lanatus* and *Festuca ovina* and by Tubeuf for certain moorland grasses—and the area of infection seems limited to the region of the stem apex. Thus, though it would appear at first sight that the progress of evolution had

* E. McLennan, The endophytic fungus of *Lolium*. Part I. Proc. Roy. Soc. Victoria, XXXII (N.S.), pp. 252–301 (1920).

† Fuchs (Hedwigia, LI, pp. 221–239 (1911)) claims to have proved that the fungus is a species of *Fusarium*.

been along a line similar to the *Calluna* type leading to infection of the embryo as apart from the seed-coat, and consequent continuous infection, it is more likely that in the typically non-mycorrhizal grasses such a union has been brought about by a subjection of a seed parasite.

Relation between Fungus and Flowering Plant.

Throughout the preceding pages incidental remarks have been made regarding the relation between the two constituents of the mycorrhizal association. The subject is one of extraordinary interest and of extreme difficulty. It does not seem possible to regard all such associations as being of the same nature or as having arisen in the same way.

As we have seen, Rylands was the first to record fungi in association with roots, though his account is not very clear: his idea that the fungus performs no essential function in the economy of *Monotropa* is one that has had few supporters.

Reissek, who in many ways seemed before his time in his attitude towards the subject, regarded the regularity and permanence of the presence of fungi in orchid roots as of great importance. He apparently considered that they were not absolutely necessary for the life of the plant and suggested that the orchid could generate without the root fungus in the same way that the greater number of flowering plants are able to propagate without flowers.

The gradual realization of the dual nature of lichens brought in its train the conception of symbiosis, but the increasing knowledge as to the nature of fungus-roots played a not inconsiderable part in the growth of the idea.

From the year 1862 Tulasne began to consider the relation between the False Truffle (*Elaphomyces*) and the roots of trees as one not of simple parasitism as he had previously (1841) thought, but one by which both organisms benefited in some way. Pfeffer in 1877 took up this idea of mutual benefit and made it more precise. Other workers—Treub, Goebel, Kamienski—also regarded the relation between fungus and root as of this description. It is to the work of Frank, beginning in 1885, that we owe a proper conception of the widespread phenomenon and a clearly outlined theory of symbiosis between fungus and root. Naturally as more facts both of observation and experiment were obtained Frank's original theory was somewhat modified—originally it was that plants with ectotrophic mycorrhiza did not themselves draw nutriment from the soil, but that the mycelial filaments which completely envelop the absorbent roots procure for it all its nutriment. Such roots always lack absorbent root hairs. The absence of these organs of absorption corre-

sponding to the presence of mycelial filaments suggests that the latter take up the functions of the former. Later, the view taken was that the fungus does not necessarily nourish the roots, but draws its nutriment from the humus of the soil and passes on a portion of this to the roots. In other words the presence of the fungus allows the root to make use of certain substances of the humus that it would be incapable of utilizing in its absence. Another hypothesis which figures largely in the literature of the subject is that of Stahl*. This author endeavours to show that the rôle of the fungus consists in furnishing the plant with mineral nutriment. Comparing plants with and without mycorrhizas he points out certain differences which always appear to indicate a much greater circulation of water in the latter. Thus their roots are strongly developed, they possess numerous root hairs, their leaves transpire energetically and are often provided with water stomata. Further, their tissues are ordinarily rich in starchy matters and poor in sugar, i.e. in a condition favourable for transpiration. The fact that mycotrophic plants transpire less† and are in consequence less well fed in nutrient soils leads to the idea that the service which the fungus renders to the host consists in remedying the insufficiency of transpiration. Stahl imagines that the fungus hands over the products of assimilation of the salts rather than the salts themselves. There exists between phanerogams and fungi growing in the humus of forests, heaths, moors, etc., a competition for the salts which the vegetable débris already contains in a concentrated form. The advantage in this struggle would apparently be on the side of the fungi owing to their mode of life. Plants with very active transpiration are alone capable of struggling with success against fungi in soils rich in humus: plants with feeble transpiration are only able to subsist in these conditions by the help which their symbiotic fungus brings.

Magnus (1900) from his anatomical investigations regarded the digesting cells as serving for absorbing the nutriment of the fungus: the lodging cells, on the other hand, are set apart for the nourishment of the fungus on the cell contents and for its hibernation. This idea would give the classical balance of symbiosis—each component benefiting to an approximately equal degree.

Gallaud regards the communication of the endophyte with the exterior in endophytic mycorrhizas as insufficient to assure to the plant the absorption of nutritive substances. From a

* E. Stahl, Der Sinn der Mycorrhizenbildung. Jahr. f. wissensch. Bot. XXXIV, pp. 539–668 (1900).

† The difficulty in drying orchid plants for herbarium purposes is a result of this.

study of numerous types of infection he holds that the fungus when in the root leads a life independent of the exterior and that it must therefore obtain all its nutriment from the plant. Comparing its mode of life with that of fungal parasites such as Peronosporaceae he decides against its parasitic nature and regards it as a special form of saprophyte—an internal saprophyte.

Ternetz working with the fungi from Ericaceae records as a result of careful experiments that they are able to fix free nitrogen. From a theoretical point of view this is of extreme interest, fitting in well with what is known concerning the bacteria in the root nodules of the Leguminosae, but so many discordant results have been recorded in such studies that it would be well not to accept these without confirmation. Incidentally it may be again remarked that Burgeff was unable to show any such fixation in orchids.

Owing to the totally different complexion that Bernard's work put upon the mycorrhiza question, his views are of particular interest. He regards the fungus in orchids as a parasite: an orchid suffers from a benign cryptogamic malady. Symbiosis for him represents the immunity realized by phagocytosis.

Burgeff on theoretical grounds considers that both orchid and fungus must benefit by increased power of reproduction. He is in general agreement with Stahl as to the nature of the benefit the flowering plant receives. The union arose originally from the ability of the fungus to take up carbon compounds from the soil. The function of the fungus in germination is to introduce a solution of carbohydrates into the seed by means of its enzymes.

Most recent workers on ectotrophic mycorrhizas regard the fungus as parasitic. Fuchs* attempted to inoculate the roots of Abietineae by adding fungus spores to the soil. He did not succeed in his experiments, but regarded the vehemence with which the young plants cut off the infected cells as an effort to prevent the attacks of a parasite.

Weyland† introduced the microchemical method of studying the question and it is probable that from such studies a clearer idea of what is really taking place will be obtainable, by the determination of the localization of nutriment. He considers that the fungus in an ectotrophic mycorrhiza is really a parasite and has nothing to do with symbiosis.

* J. Fuchs, Ueber die Beziehungen von Agaricineen und anderen humusbewohnenden Pilzen zur Mycorhizenbildung der Waldbäume. Bibliotheca Botanica, LXXVI (1911).

† H. Weyland, Zur Ernährungsphysiologie mykotroper Pflanzen. Jahr. f. wissensch. Bot. LI, pp. 1–80 (1912).

Weevers* working from a chemical point of view on the presence of ammonia and ammonium salts in plants established the fact that although ammonium salts were found in abundance in the tubercles of the Leguminosae they were in small quantity or absent in mycorrhizal plants. He holds therefore that if fungus-roots really assimilate nitrogen it must be brought about in a manner different from that in the Leguminosae. Weevers is rather of the opinion that mycotrophic plants are, with the help of their fungus partner, able to utilize fully the organic compounds of the soil.

McDougall†, working with ectotrophic mycorrhizas of forest trees formed by the association of toadstools with the roots, considers that they are not in any sense symbiotic associations but must be considered as instances of parasitism by the fungi.

Rexhausen‡ studied ectotrophic mycorrhizas by the micro-chemical method. He considers that the fungus and the root together form an osmotic unit for the absorption of nutrient salts. These are probably made soluble for the root by the fungus. This gathering up of nutrient salts is first used by the fungus for its own benefit. The mycorrhiza is not a fixed symbiotic condition, but is dependent upon the biological condition of the soil. Where the conditions are not suitable for the growth of the fungus it acts as a parasite on the root and may damage it severely, as it cannot be kept in check. Where the fungus is well nourished it can be easily withstood by the root. Thus in good soils the mycorrhiza gradually disappears or, at all events, the fungus part becomes less.

It will be apparent from the above that many somewhat diverse theories have been put forward to account for the fungus-root association and many modifications have been proposed. No purpose would be served here by entering on a detailed criticism: the only general one we would suggest is that no benefit can result from pushing the old idea of mutual and equal advantages of the two components to its extreme. Referring only to orchids it seems most reasonable to regard the condition as having arisen from parasitic attacks by the fungus. This seems beyond doubt in the exceptional case of *Armillaria* and *Gastrodia*. The ability of the fungus to transport nutrient solutions has been made use of by the flowering plant. As in the case of Leguminosae and their nodules the tables have been

* T. Weevers, Das Vorkommen des Ammoniaks und der Ammonsalze in den Pflanzen. Recueil des Travaux botaniques Néerlandais, XIII, pp. 63–104 (1916).

† W. B. McDougall, On the mycorrhizas of forest trees. American Journ. Bot. I, pp. 51–74 (1914).

‡ L. Rexhausen, Über die Bedeutung der ektotrophen Mykorrhiza für die höheren Pflanzen. Beit. z. Biol. der Pflanzen, XIV, pp. 19–58 (1920).

turned and the "host" has become the aggressor, even attracting the fungus to the embryo. We are short of definite facts—there is a conflicting mass of detail on such an important point as the relation between the endophyte and the soil—and until these are obtained one theory seems as good as another.

It would be indeed strange if the difference between ectotrophic and endotrophic mycorrhiza should resolve itself into a case of the fungus being parasitic on the flowering plant in the former, while in the latter the flowering plant is parasitic on the fungus.

I am indebted to Mr E. H. Ellis for the photomicrographs, with the exception of Figs. 1 and 4, for which I must thank Mr R. J. Tabor.

While the above was in the press an important paper by H. Christoph entitled "Untersuchungen über die mykotrophen Verhältnisse der 'Ericales' und die Keimung von Pirolaceen" appeared in Beih. Bot. Centralbl. XXXVIII, pp. 115–157 (1921). In it the author controverts the results obtained by Rayner concerning the necessity of the root-fungus for seed-germination (cf. p. 48). It should be noted, however, that he has not seen the full description of Dr Rayner's researches, but apparently only an abstract of her preliminary account. Christoph concerned himself with the manner in which the fungus reaches the roots of the Ericaceae, whether from the soil or from the seed coat. His first series of experiments were performed with cuttings. He took both large and small green side shoots from plants of *Calluna vulgaris* both wild and cultivated. These were planted in shallow pots in humus heath soil—the soil in the one pot being sterilized and that in the other not. In both experiments a number of cuttings struck and succeeded in establishing themselves. The roots of the cuttings in unsterilized soil became slightly infected, but no fungus could be found in those growing in sterilized soil. On replanting and transferring the latter cuttings to sandy soil they still remained free from fungal infection and continued in that condition for two and a half years.

Similar experiments with cuttings of *Erica carnea* gave analogous results. Both series succeeded and those planted in sterile black heath soil, and after one and a half years transferred, remained free from fungus infection for two and a half years.

The plants without fungi in their roots were in just as good a condition as those which became infected and Christoph is of the opinion that the fungus is of no assistance to the plants and must be regarded as a harmless parasite.

A second part of the paper deals with germination experi-

ments with these two species. The results of thirteen experiments are summarized, though the complete account is not published.

Different soils were tried, both sterilized and unsterilized. Seeds of *Calluna* and *Erica* were sown in these, some having their coats sterilized, some being used just as they were taken from the capsules. The results were similar in both series of experiments, except that *Erica carnea* germinated only in the absence of light. Germination occurred in all experiments, e.g. sterilized seeds germinated in sterilized soil. Only those seedlings growing in unsterilized soil become infected with fungus whether the seeds are sterilized previously or not; in certain cases seeds which were taken from capsules in which a fungus was very obvious did not give rise to infected seedlings when sown in sterilized soil. The author concludes that infection of the root always comes from the soil and never from the seed coat.

Regarding infection in the capsule, Christoph states that so long as the carpels are still green and the seed white a fungal infection of the tissue can never be observed.

The author succeeded in extracting the fungus from the roots of the plants, but was unable to obtain spores in pure culture and was therefore unable to identify it. That it was probably the appropriate fungus was shown by infecting seedlings of both *Calluna* and *Erica*.

The Ericales are considered to be facultative mycotrophic plants, since specimens growing in normal conditions always have fungus in their roots. In very dry places, however, plants of *Calluna vulgaris* and of *Erica carnea* are often without fungi; and in pot cultures allowed to become dry the fungus soon disappears.

The third portion of the paper deals with the Pyrolaceae. Working with *Pyrola uniflora*, *P. secunda*, *P. minor* and *P. rotundifolia* it was found that the hyphae of the infecting fungi had clamp-connections (and were therefore probably Basidiomycetes). The conclusion reached is that here also no true "symbiosis" exists—infection depends upon many external factors, of which temperature, soil, moisture and aeration are the chief. Coralloid roots are not brought about by infection: there is a special development of the large epidermal cells and these, owing to their function of absorption, are specially suited for fungal development.

In *Monotropa* the fungus possesses no clamp connections.

The author was successful in germinating seeds of *Pyrola rotundifolia* which he chose, as they were the largest of the four species. The best results were obtained from: 1. Strong concentrated soil-extract. 2. Addition of peptone solution. 3. Sowing

on humus from habitat of plant—on sterilized soil there was no germination. 4. Keeping cultures in the dark. 5. Moderate moisture.

It is suggested that the carbon compounds of the highly concentrated soil extract, acting in combination with the peptone, brought about germination by chemical action.

Parallel experiments with peptone solution alone, soil extract alone, and with a mixture of both gave a slight germination in peptone solution, a stronger one in soil extract, but much the best is a mixture of the two.

With regard to the question of infection of the seedling root from the capsule it is obvious that there is great discrepancy between the accounts of Rayner and Christoph, and until the results of one or other worker be confirmed it is not possible to draw from them theoretical conclusions. That cuttings of *Calluna* can strike and come to maturity in sterilized soil without root infection is somewhat unexpected on account of Rayner's clear description of the distribution of the fungus in the plant; in cultivated orchids it is quite likely that after the seedling stage fungal infection is not necessary.

Concerning the germination of *Pyrola rotundifolia* seeds the account is not full enough to draw from it any theoretical conclusions. The fact that the seeds can be brought to germinate by chemical means is not surprising: it is analogous to what has been found by Bernard in *Cattleya*. There was apparently no attempt made to try the effect of the root-fungus on germination.

EXPLANATION OF PLATES.

Plate II.

Fig. 1. Transverse section of root of *Habenaria* just above the root tip. The dark masses show where digestion of the fungus is taking place. × 36.

Fig. 2. Seed of *Cymbidium*, stained and mounted whole. The embryo is seen as an oval black patch within the network integument. × 56.

Fig. 3. Longitudinal section of a seed of *Odontoglossum*. The anterior end shows smaller cells, the posterior end larger cells. (The integument has been ruptured in making the preparation.) × 215.

Fig. 4. Fungus from *Odontoglossum* (*Rhizoctonia lanuginosa* Bern.) at the beginning of sclerotium formation. × 36.

Fig. 5. The same more highly magnified showing chains of "spores." × 215.

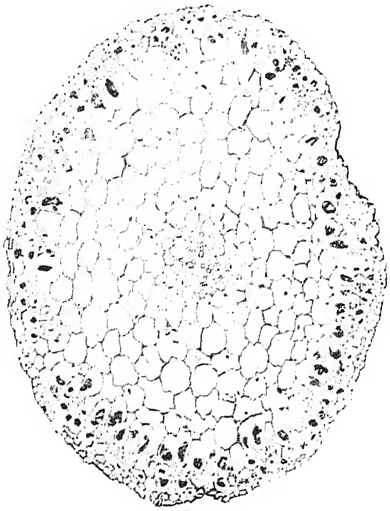
Plate III.

Fig. 6. Seed of *Odontoglossum* sown seven days on a culture of the fungus: stained and mounted whole. × 56.

Fig. 7. The same more highly magnified. × 215.

Fig. 8. Longitudinal section of a seed of *Odontoglossum* nine days after sowing. The fungus has entered the larger cells at the suspensor end of the seed and formed balls of hyphae. (The integument has been broken in cutting the section, cf. Fig. 6.) × 215.

Fig. 9. Section of protocorm of *Odontoglossum*. The growing point of the stem can be seen at the upper end and the first and second leaves (Section



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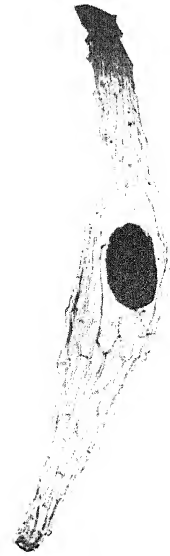

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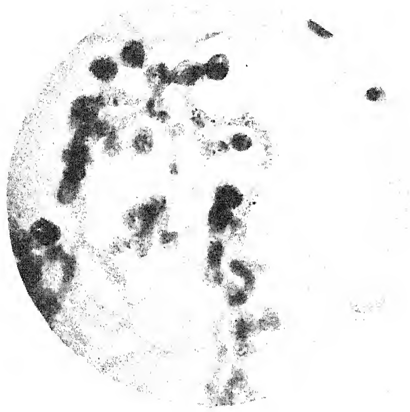

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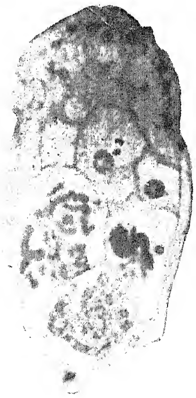

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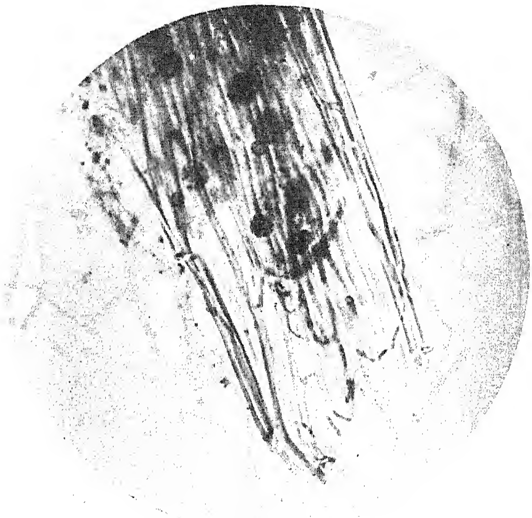

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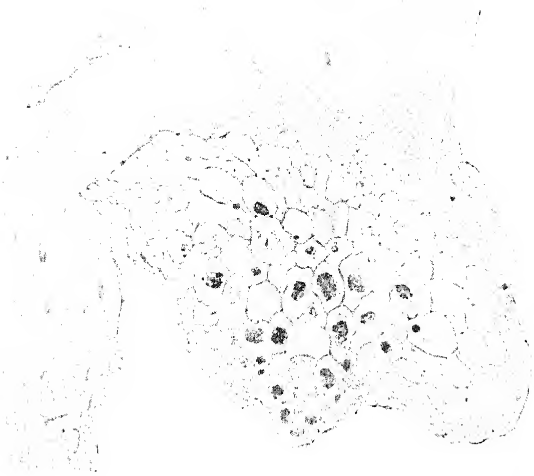

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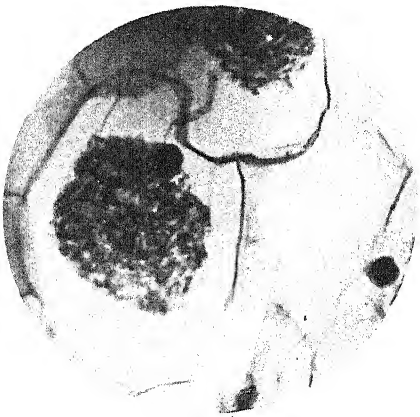

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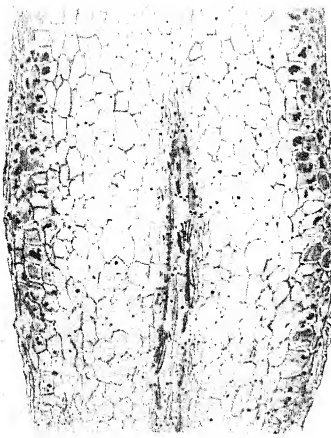

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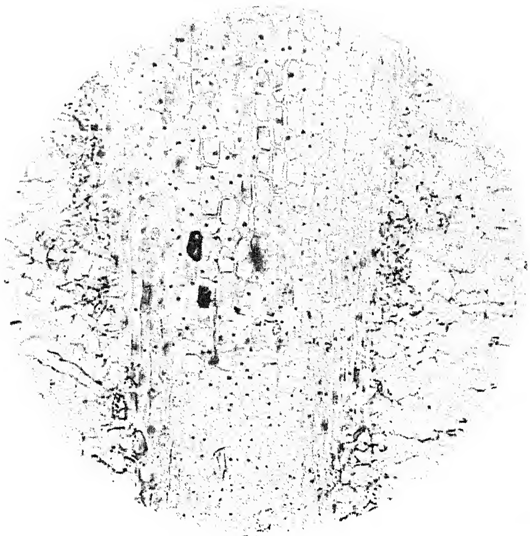

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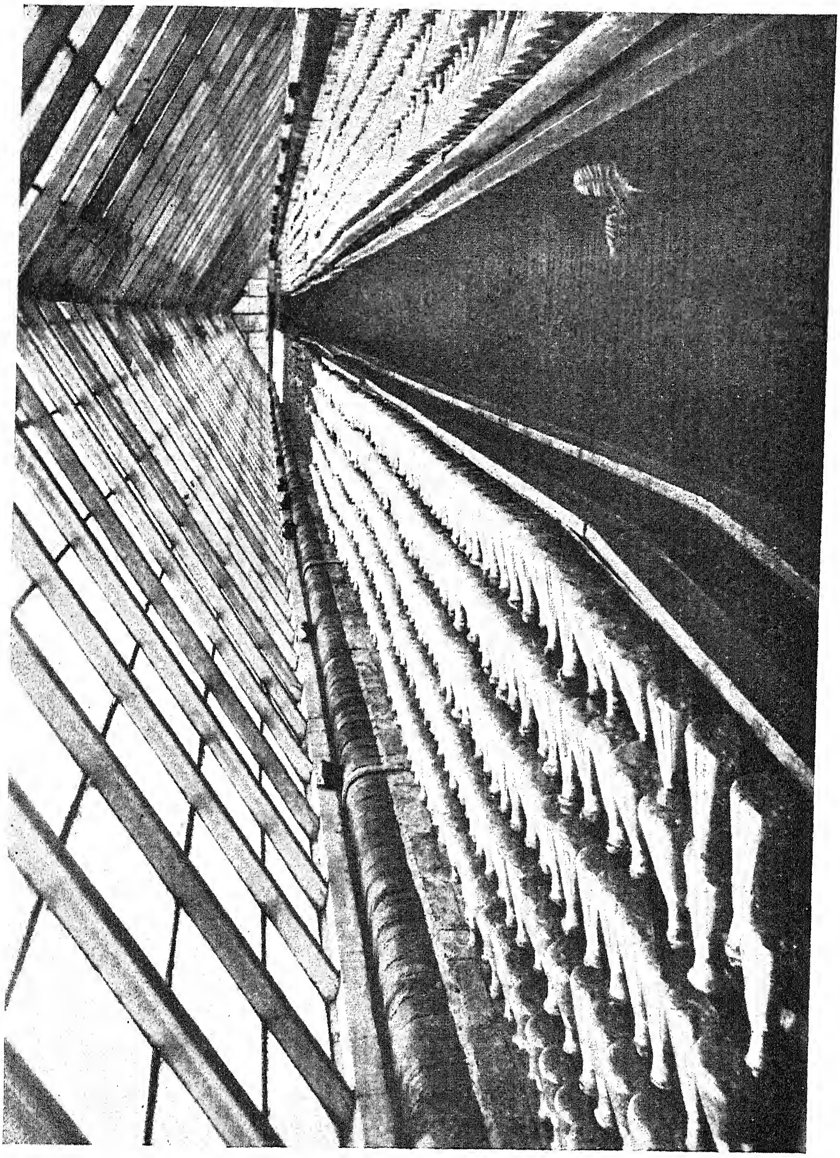

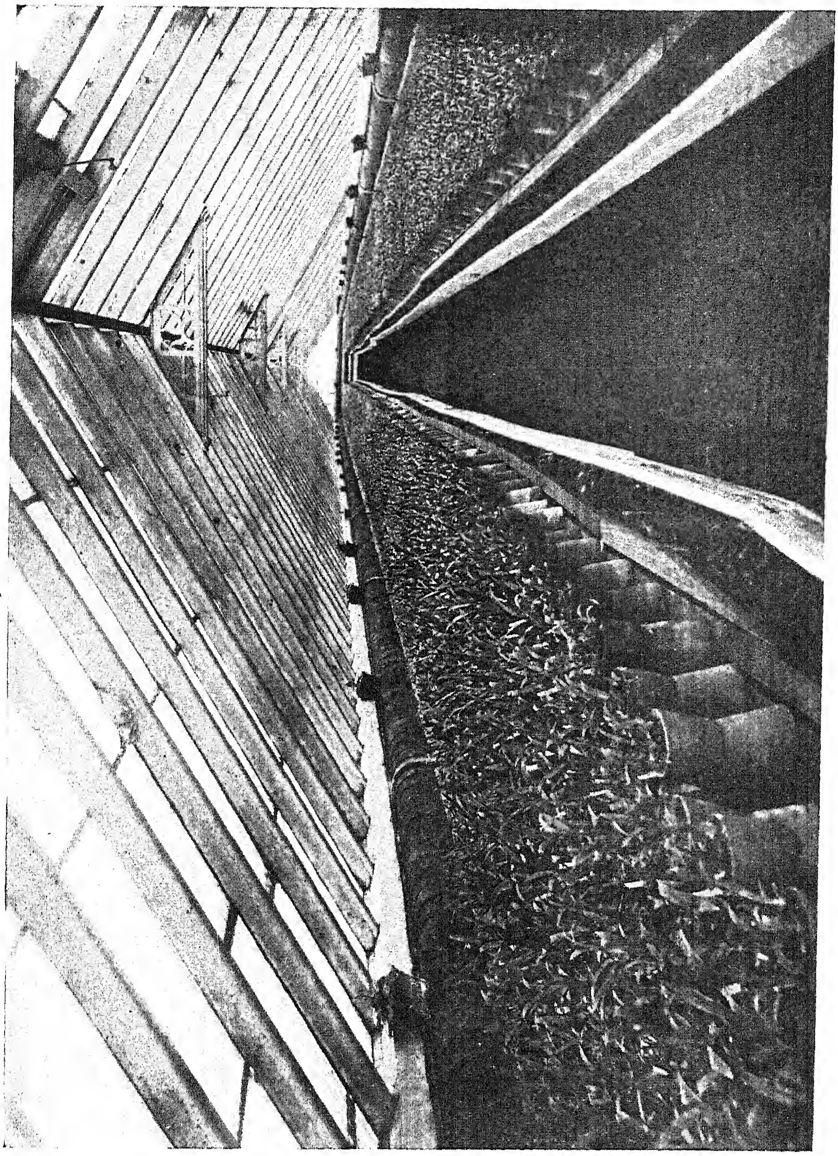

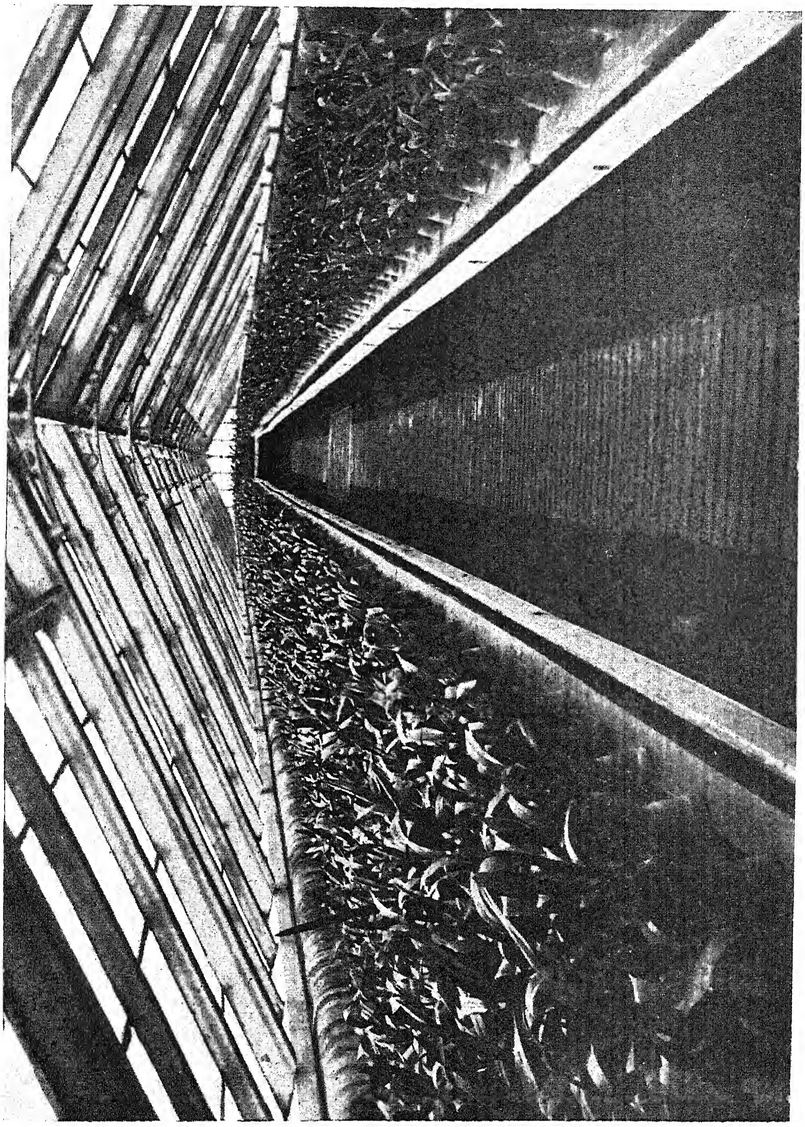

not quite median). The fungus in many of the cells is already digested. ×56.

Fig. 10. Later stage of *Odontoglossum* showing the beginning of the formation of the central stele and root. The stem growing-point is well developed. The fungus in the cells is mostly digested. ×36.

PLATE IV.

Fig. 11. Protocorm of *Vanda* showing the young root absorbing its way out of the side of the protocorm away from the fungal zone. ×18.

Fig. 12. *Odontoglossum* seedling after the formation of the first root. The root is not infected from the protocorm. (The dark patches in the root are raphides.) ×36.

Fig. 13. Cells from fungal zone of Fig. 12 more highly magnified. The fungus is "clumped" (cf. Fig. 8). A fungal hypha is seen passing through the cell-wall. ×215.

Fig. 14. Longitudinal section of the root of *Habenaria* near the tip. Digestion is more prominent in the older (upper) portion of the root. ×18.

Fig. 15. Longitudinal section of an aerial root of *Epidendrum* showing infected cells in the centre and mycelium in the velamen. ×18.

PLATE V.

Odontoglossum house; first stages of seedling raising by the "pure culture" method.

PLATE VI.

Odontoglossum house; seedlings one year old grown by the "pure culture" method.

PLATE VII.

Odontoglossum house; seedlings three and four years old.

MYCORRHIZA IN THE ERICACEAE.

By M. Cheveley Rayner.

There has recently been published a paper by Christoph (1) containing an abridged account of researches carried out by him on the relations between plant and mycorrhizal fungus in the Ericaceae. The species studied were *Calluna vulgaris* and *Erica carnea* and that part of the investigation with which the present critical review deals is concerned with (*a*) the behaviour of "cuttings" of the shoot, and (*b*) seed cultures of the former plant.

With the researches on "cuttings" I do not propose to deal at present as it is hoped that a paper may be ready for publication in the near future detailing the results of my own experiments in the same direction. With regard to the work on seed cultures of *Calluna*, the experimental results recorded by Christoph are so remarkably at variance with those published in 1915 (2) and since that time repeatedly confirmed by me, that I welcome the present opportunity of discussing them in some detail.

As a starting-point of my own investigations may be taken the simple observation that seed of *Calluna* germinated on moist filter paper in a germinator yields seedlings which root freely in the seed dishes, the roots showing regular fungal in-

fection of the kind typical to the plant. In such seedlings infection by hyphae from the seed coats can commonly be observed and similar observations have been made on seeds germinating viviparously within the fruit by Ternetz(3) for *Calluna* and by me for *Pernettya mucronata*. Moreover, it is often possible to observe the presence of fine hyphae upon the seed coats of ripe seeds taken from *unopened* fruits, the observation of which may be facilitated by the use of careful methods of maceration. Interovarial infection can be demonstrated in sections of unripe fruits with the aid of a very careful technique, although such demonstration of infection of seeds within the ovary usually involves a relatively large amount of tedious and painstaking work. I am of opinion that extensive infection of the seed coats occurs only at a late stage, and is probably associated with death and desiccation of the tissues composing the fruit-wall and the increased mycelial activity subsequent to this.

In my experience, very careful work and much patience are needed to obtain convincing proofs of the presence of mycelium within the ovary and young fruit. For this reason I do not attach great importance to Christoph's failure to observe it. I have offered elsewhere what I believe to be convincing evidence on this matter (*loc. cit.*).

The technique adopted by me to obtain seeds free from infection is as follows. Seeds, freed from all impurities, are wetted by centrifuging, they are then sterilized by immersion in 1 % mercuric chloride for three minutes and, after repeated rinsings in sterile water, sown on agar media containing sugar and peptone to facilitate the detection of micro-organisms if present. In my original experiments, seedlings from such pure cultures were transferred to tubes of broth and bouillon kept at various temperatures, in order to test in the most drastic way possible their freedom from micro-organisms (*loc. cit.*).

Seedlings raised in this way and planted in nutrient agar suitable for their growth do not develop a root system and eventually die; if inoculated at planting from a suitable pure culture of the endophyte *isolated from the ovary or unopened fruit*, they develop normally in every way and the roots show typical infection.

Every link in this chain of events has been demonstrated experimentally and there is no escape from the following conclusions:

(*a*) That under the experimental conditions described development of the *Calluna* seedling is bound up with infection.

(*b*) That such infection takes place regularly from the testa of the seed at, or subsequent to, germination.

As a further result of experimental work I claim also to have shown that infection of the seeds within the fruits takes place as a consequence of the widespread distribution of the endophyte throughout the plant body. The evidence for this need not be discussed here, but it may be pointed out that the production of infected roots by "cuttings" rooted in sterilized sand under aseptic conditions would provide convincing confirmation of the presence of the fungus in the shoot tissues.

To pass to Christoph's work on seed cultures. The behaviour of seeds and seedlings was investigated as follows:

(*a*) *Unsterilized seeds on sterilized soil.*

Seeds were subjected to prolonged soaking in rain water and sown on peat (Torfmulle) sterilized by repeated autoclaving: controls were sown on untreated peat.

After six months it is recorded that the seed sown on sterile peat had produced seedlings 7–11 mm. high with root systems 24 mm. long *in all cases entirely free from fungus infection.* Other cultures of a similar kind gave on unsterilized soil, seedlings with roots infected: on sterilized soil, seedlings equally vigorous with roots which were still entirely free from fungal infection a year after sowing.

With regard to these results it may be pointed out that until my claim of seed coat infection has been disproved, all seedlings raised from unsterilized seed would be assumed liable to infection at germination. In my own researches, I have been careful to use seed from as many different sources as possible, but have never observed a case of non-infection of roots in experimental plants, nor have I ever found a plant growing under natural conditions or under cultivation without mycorrhiza. I do not deny the possibility that such plants may exist; I can only affirm my own experience in this matter. On the other hand, it is not always easy to observe infection in the clean roots of seedlings and in the absence of opportunity to examine the material, it is only possible to assume that the presence of mycelium in the roots of these seedlings has been overlooked by Christoph.

(*b*) *Sterilized seeds on unsterilized soil.*

Seeds were sterilized in various ways: in the later experiments by means of 1 % mercuric chloride. After sterilization they were sown on a suitable soil from a *Calluna* area (Diesenhofenen Erde). These cultures are recorded as giving after six weeks seedlings 5–10 mm. high with roots normally infected. Christoph assumes that these experiments provide conclusive proof that infection by the mycorrhizal fungus takes place *only* from soil.

Clearly this is not the case. All the seeds were sown on peaty soil without controls on sterile media and no proof of any kind is offered that the seeds were adequately sterilized. If the soil used was from a *Calluna* station infection evidently could take place from roots in such soil, as it may do in nature in the case of seedlings germinating near the parent plant.

The view has never been put forward by me that the endophyte is not present in soil or that infection *cannot* take place from this source. On the contrary, it is obvious that the soil of an area occupied by *Calluna* will always contain the fungus. Concerning the distribution of the endophyte in soil generally I have at present no data, nor have I expressed any opinion as to its independent occurrence in nature apart from the *Calluna* plant.

(*c*) *Sterilized seeds in sterilized soil.*

Seeds were sterilized with 1 % mercuric chloride. The soil brought from a *Calluna* area (Diesenhofen) was repeatedly autoclaved at 140° C. It is recorded that at the end of five months the experimental seedlings were well rooted, the roots being entirely free from infection by fungal hyphae. As in the experiments described under (*a*), no proof of seed sterility is offered. Until such proof can be supplied, it is only possible to repeat the criticisms under (*a*).

It is greatly to be desired that Dr Christoph should repeat these experiments providing rigorous proof of seed coat sterility subsequent to sterilization, and that he should then maintain his cultures under aseptic conditions. It is not recorded that any attempt has been made to do this in the case of those described and the possibility of air-borne infection of sterile cultures is ignored. It appears to the writer that just conclusions as to the biological relationships between organisms found growing in close association in nature can only be reached as the result of "pure culture" work which will pass the tests demanded by any competent bacteriologist. Anything less is obviously unsatisfactory and cannot yield conclusive evidence. The following quotation from Christoph's paper shows how far from this ideal were the cultures upon which he bases his conclusions:

"Anfangs machten sich einige Zeiten hindurch Rasen von *Mucor* und *Citromyces* unangenehmen bemerkbar, ohne jedoch Schaden unter den Pflanzen anzustiften. Wie bereits anlässlich die Beschreibung der *Calluna*-Steckling Kultur erwähnt wurde sind diese Pilze nicht imstande die Wurzeln zu infizieren, weshalb ein Nachteil für die Sicherheit des Ergebnisses auch nicht zu befürchten war."

The number of seedlings dealt with is not always mentioned.

When it is, criticism is invited, e.g. ten seedlings in one experiment, eleven seedlings in another. Numbers so low in the case of seeds so small as those of *Calluna* raise grave doubts as to the general conditions of the cultures.

Again, the proof offered by Christoph of the identity of a fungus, isolated by him from clean pieces of *Calluna* root, with the endophyte is unsatisfactory. So far as is possible to judge from the description of morphological characters, the right fungus was isolated from the root although spores were not produced. *Positive proof of identity can only be supplied by inoculation into a pure culture seedling growing under controlled conditions with subsequent production of mycorrhiza.*

The method adopted was to sow *unsterilized* seeds in pots of sterilized soil, and transfer the seedlings so obtained to pots of sterilized soil inoculated with the fungus he had isolated from roots.

According to Christoph the first roots of such seedlings remained sterile, the numerous laterals which developed became typically infected. On my view, such seedlings would always become infected at germination, their establishment as rooted plantlets depending upon this. Even assuming the seed coat to be free from infection by the specific root fungus, the method used by Christoph is obviously incapable of providing the strict proof of identity required.

Attention has already been drawn by me (*loc. cit.* p. 6.) to the possibility of replacing the stimulus to development normally provided by the fungus by stimuli of a chemical nature, e.g. by the addition of organic substances to the rooting medium in which seedlings are growing. It is even conceivable that an appropriate organic substance might be present in sterilized peat and so provide an explanation of the discordant experimental results recorded by Christoph. This possibility is now being fully explored.

In conclusion, may I add one word as to the experimental difficulties experienced in work of the kind under discussion? After many years' work I am still far from a complete understanding of the co-ordination shown by plant and endophyte in Ericaceae. There is, for example, a close and, at present, unexplained correlation between germination of the seed and activity of the mycelium on the seed-coat. Again, the presence of the endophyte in the tissues of the shoot and within the unopened fruit makes its isolation theoretically a simple matter; in practice this is difficult, and I am still ignorant of the exact conditions which determine the ability or otherwise of the fungus to grow out from the tissues.

Owing to the extreme delicacy of the balance between seed-

lings and endophyte, the production of "synthetic" seedlings is not a simple operation. The age of the seedling, the suitability or otherwise of the rooting medium, the age of the fungus culture and the nutrient on which the endophyte is cultivated outside the plant are all critical factors, as are also doubtless such formal external conditions as temperature, moisture, and light.

REFERENCES.

(1) CHRISTOPH, H. Untersuchungen über die mykotrophen Verhältnisse der "Ericales" und die Keimung von Pirolaceen. Beih. Bot. Centralbl. XXXVIII, pp. 115–157 (1921).
(2) RAYNER, M. C. Obligate symbiosis in *Calluna vulgaris*. Ann. Bot. XXIX, pp. 97–133 (1915).
(3) TERNETZ, C. Über die Assim. des atmosphär. Stickstoffes durch Pilze. Jahrb. f. wiss. Bot. (Pringsheim), XLIV, pp. 353–408 (1907).

AN EOCENE MICROTHYRIACEOUS FUNGUS FROM MULL, SCOTLAND.

With Plate VIII.

By W. N. Edwards, B.A., Department of Geology, British Museum.

Well-preserved fossil fungi are of comparatively rare occurrence, and most of those so far described are found in petrified material. Names have certainly frequently been given to spots and markings on leaf impressions, which, however, rarely show any structure and are of very little botanical value. It is therefore of interest to be able to record the discovery in some Tertiary Rocks of Scotland of an unusually well-preserved epiphyllous fungus.

The Eocene interbasaltic beds of Mull contain a varied flora of ferns, conifers and dicotyledons mostly preserved as impressions. In a very few cases the actual leaf cuticles have remained practically unchanged in what has been called a "mummified condition," and by treatment with Schultze's mixture or some other reagent can be cleared and examined microscopically. This method of preservation is familiar to palaeobotanists, who have found the details of stomatal structure and cell outline valuable aids to classification, especially in the case of certain gymnosperms.

The microscopic fungus about to be described was found in the course of examining some linear coniferous leaves scattered on the surface of two slabs of rock in the Starkie Gardner Collection (Specimens V, 14846 and 7). With the object of

studying the leaves themselves, small fragments of the cuticle were detached from the rock and treated with nitric acid and potassium chlorate, followed, after washing, by ammonia. This process removes the carbonaceous matter and leaves a clear brown cuticle which can then be mounted in glycerine, the upper and under epidermis being first separated with needles. Some very small dark spots, which could not be seen before treatment, were then observed with the naked eye on the clear cuticle, and these proved on microscopic examination to be discoid bodies with a radiate structure which at once suggested a small epiphyllous fungus. I showed the specimens to my colleague, Mr J. Ramsbottom, who expressed the opinion that they probably belonged to the Microthyriaceae. In the subsequent study of this fungus I have continually received much help from Mr Ramsbottom and I am greatly indebted to him for his advice and assistance.

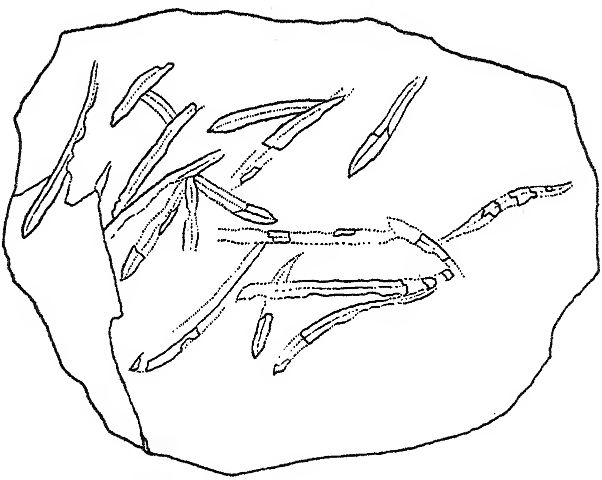

FIG. 1. Slab of rock with *Pityophyllum* sp., a coniferous leaf attacked by *Phragmothyrites*. Eocene, Mull. Brit. Mus. (N.H.), Geol. Dept. no. V. 14846. Nat. size.

Description of the material. The discoid bodies, which are regarded as the ascostromata (or "thyriothecia") of a Microthyriaceous fungus, occur singly, or rarely in concrescent pairs, on the upper surface of the leaf, and in some preparations are scattered over it in considerable numbers (cf. Pl. VIII, fig. 1). They are usually practically circular, and the largest specimen

is about 165 μ in diameter. They have a regularly radiate structure and the margin is entire, or very slightly crenate, but never fimbriate. None of the specimens show a definite ostiole, but this may be due to immaturity, while on the other hand there is an appearance in some ascostromata of an irregular dehiscence such as occurs in some recent members of the family, e.g. *Asterina*, but appearances in fossils such as this are liable to be deceptive, and might be due to post-mortem or post-fossilization changes. There is no mycelium on the surface of the leaf, but stigmocysts (Pl. VIII, figs. 5 and 6) are abundant, and all stages of growth are to be found between them and the largest of the ascostromata. The stigmocysts (unicellular capitate hyphopodia) are circular and deeply crenulate, about 10–12 μ in diameter, and the clear central spot is usually distinctly seen.

No asci have so far been found, but Pl. VIII, fig. 7 shows a large 5-celled spore (? ascospore), 43 μ in length and 25 μ in breadth, which appears to be sending out delicate hyphae at each end. Another slide shows a similar spore, rather shrunken, with apparently only four cells. It seems quite probable that these spores belong to the same species as the ascostromata, though of course one cannot be absolutely certain. At any rate there is no other recognisable fungus on the leaves to which they might belong. There are a few detached fragments of hyphae and some spore-like bodies which may perhaps be mentioned here, but which may not even be of fungal nature.

The reference of a fossil fungus to its exact systematic position is not an easy matter, even when the material is so well preserved as in the present case. There are certain characters which are used in the classification of recent fungi which cannot be observed in a fossil, e.g. the colour of the spores, and moreover dissociated objects cannot always be proved absolutely to belong to the same species. In this instance one can at least feel fairly certain that the fossil is to be placed in the Microthyriaceae, though the exact generic reference is more difficult.

The Microthyriaceae and other "asterinoid" fungi have received considerable attention of late years, and their classification and relationships have been critically studied and revised by von Höhnel, Theissen, Arnaud and others. Desmazières' genus *Microthyrium* (1841) was made the type of the family Microthyriaceae by Saccardo in 1883, and this family subsequently became the dumping ground for many heterogeneous forms which have since been excluded, while on the other hand detailed study has resulted in the separation of many new genera. The classification of Theissen (1913, 1 and 1913, 2) forms the basis of our present knowledge. He groups together

the Microthyriaceae, the Hemisphaeriaceae and the Trichopeltaceae in a new order, the Hemisphaeriales, which are all superficial, and are thus sharply marked off from the Dothideales, in which the ascostromata are developed beneath the cuticle. For the hemisphaerical fruiting bodies he adopts von Höhnel's term thyriothecium. The distinctive characters of the Microthyriaceae, with which we are particularly concerned here, are the radiate (very rarely linear) dimidiate thyriothecia, on the "inverse" method of whose development von Höhnel and Theissen lay great stress. They regard the thyriothecium as corresponding to the basal half of the spherical body such as occurs in related families (e.g. Perisporiaceae) which has become inverted against the leaf surface. The family is subdivided according to the presence or absence of a free mycelium, the number of cells and colour of the ascospores, the presence or absence of paraphyses, and so on. This classification is adopted with slight modifications by E. M. Doidge (1920) where a résumé of the general characteristics of the group will be found.

Arnaud (1918) proposes a somewhat different classification based on that of Spegazzini, and uses the term Microthyriaceae in a rather wide sense, while excluding, however, certain genera such as *Amazonia*. Arnaud gives the pycnidial forms a special name (Microthyriopsidaceae); the pycnidia resemble the thyriothecia as a general rule, and therefore we cannot be quite sure which we are dealing with in the present case. Certain spore-like bodies on the leaf cuticle might perhaps be conidia.

The form of the thyriothecia in the fossil is very similar to that of *Microthyrium* itself, while in this and allied genera the mycelium is absent or evanescent. Presuming the ascospore to belong to the same species as the fruiting bodies, a relationship is indicated to the genus *Phragmothyrium* of von Höhnel (1912, p. 347) which was instituted to include "*Microthyrium* species with more than 2-celled spores." *Amazonia* Theiss. is also phragmosporic (5-celled) but has a persistent mycelium and rather different thyriothecia with fimbriate margins. It is therefore suggested that the name *Phragmothyrites* be used for fossil forms belonging to the Microthyriaceae, the exact position of which is uncertain, but which appear to be most closely related to *Phragmothyrium* as defined by von Höhnel. The Mull specimen may be described as *Phragmothyrites eocaenica* n.sp. Thyriothecia circular, radiate, with entire margin, scattered singly (rarely concrescent) on the leaf surface; stigmocysts circular and deeply crenulate; ascospores (?) 5-celled; mycelium ? absent or evanescent. Occurring on coniferous leaves (*Pityophyllum* sp.) in beds of Lower Eocene age, Mull, Scotland.

I have only succeeded in finding a few other references to

fossil fungi belonging to this family. *Microthyrites disodilis* Pampaloni (1902, *1*, p. 251; 1902, *2*, p. 127, Pl. XI, fig. 1) occurs in the disodil of Melilli, Sicily, probably of Middle Miocene age. From Pampaloni's description, an affinity with the Microthyriaceae is quite possible, but the illustration leaves much to be desired. The material is said to consist of simple, scattered, shield-shaped perithecia, composed of polygonal concentric cells, and there is no reference to spores or mycelium. Altogether the record seems rather doubtful.

Engelhardt and Kinkelin (1908, p. 185) record a few leaf-fungi from the Upper Pliocene of Klärbecken near Frankfurt-am-Main, and among them one which they refer with a query to a living species, *Asterina Ilicis* Ell., on leaves of *Ilex*. They describe circular thyriothecia (sometimes concrescent), 80–90 μ in diameter, with a crenate margin and a central ostiole when mature. Their drawing certainly closely resembles a Microthyriaceous fruit-body, and they state that an affinity to *Asterina* is indicated by the presence of a free mycelium ("Luftmyzel"), which however is not figured. They further record similar fruit-bodies on *Buxus* leaves, but smaller, with an entire margin, and without any free mycelium. Kräusel (1920, p. 338, text-fig. 7, p. 353) describes some similar bodies from the Miocene of Silesia, about 70 μ in diameter, found associated with *Sequoia langsdorfii* leaves, and apparently connected with hyphae. They are regarded as probably belonging to the Microthyriaceae. In neither of these cases were any spores found.

"Hyphae and haustoria of an *Asterina*-like fungus" occur on the cuticle of *Sequoia langsdorfii* from Tertiary beds (exact age unknown) of Ellesmere Land, lat. 77° N., and are described and figured by Nathorst (1915). The resemblance to the mycelium and stigmopodia of *Asterina* and other allied genera is certainly very striking. It is interesting to note that this fungus was discovered in the same way as *Phragmothyrites eocaenica* and the fungi described by Kräusel, by chemical treatment of a coniferous cuticle, and the preservation of the mycelium suggests that had *P. eocaenica* possessed a persistent mycelium it would also have been preserved.

The identification of the host plant presents some difficulties, but it is best referred to provisionally as *Pityophyllum* sp. (a name used for fossil coniferous leaves of uncertain affinity). A somewhat similar conifer, *Podocarpites campbelli* (Gard.), is a common fossil at Mull, but the leaves are usually larger and more acuminate. The scattered leaves of the present specimen, as shown in Text-fig. 1, may be compared with a figure of *Podocarpus suessionensis* Wat., given by Crié (1878, Pl. VII, fig. 32) of a specimen from the Eocene of Sarthe, but here again

it should be noted that the Mull leaves are not so acuminate. The identification even of leafy coniferous twigs is not easy, so that the attribution of detached leaves must be very uncertain. In the present instance, however, the cuticle preparations show to some extent the structure of the stomata, and these were kindly examined for me by Miss H. Bandulska, who made a series of comparative measurements. She believes that the stomata were of a type found in *Sequoia sempervirens* and some species of *Araucaria* and *Podocarpus*, the greatest resemblance being to those of *Podocarpus melangianus*. The host plant of *Phragmothyrites eocaenica* may therefore possibly be a *Podocarpus*. The question of its stomatal structure and identity will be dealt with more fully in another place. No other leaves from Mull yield cuticles, with the exception of *Ginkgo adiantoides* Ung. on which no traces of fungi have been found.

The presence of this epiphyllous fungus would seem to indicate fairly moist conditions of growth. The living Microthyriaceae are mainly tropical, but rainfall rather than temperature would appear to be the important factor influencing distribution. Arnaud (1918, p. 31, etc.) asserts that "asterinoid" fungi are confined to parts of the globe with more than one metre of rainfall per annum. Prof. A. C. Seward and Mr R. E. Holttum, who kindly allowed me access to a forthcoming paper on the Mull fossil plants, consider that the flora indicates a temperate climate, but warmer than that of the present day in the same latitude, and they speak of the possible presence of evergreen shrubs as another indication of a warm, fairly moist climate. They see no reason to modify Gardner's opinion that the beds are of Lower Eocene age.

In conclusion we may note that very few living species of Microthyriaceae have been recorded from Great Britain.

BIBLIOGRAPHY.

ARNAUD, G.—Les Astérinées. Thèses présentées à la faculté des sciences de Paris. Montpellier, 1918.

CRIÉ, L.—Recherches sur la Végétation de l'Ouest de la France à l'Époque Tertiaire. Thèse présentée à la faculté des sciences. Paris, 1878.

DESMAZIÈRES, J. B. H. J.—Huitième Notice sur quelques plantes Cryptogames. Ann. Sci. Nat. sér. II, XV (Bot.), pp. 129–146, 1841.

DOIDGE, E. M.—South African Microthyriaceae. Trans. Roy. Soc. South Africa, VIII, pt. 4, pp. 235–282, 1920.

ENGELHARDT, H. and KINKELIN, F.—Oberpliocäne Flora und Fauna des Untermaintales. Abh. Senckenberg. Naturf. Ges. XXIX, 1908.

GARDNER, J. S.—Mon. Brit. Eocene Flora, II, 1883–6. Pal. Soc. London.

HÖHNEL, F. VON.—Fragmente zur Mykologie, XIV, No. 725. Sitz. k. Ak. Wiss. Bd. 121, Abt. I, p. 346, 1912.

KRÄUSEL, R.—Nachträge zur Tertiärflora Schlesiens, I. Jahrb. Preuss. Geol. Land. f. 1918, XXXIX, 1920.

NATHORST, A. G.—Tertiäre Pflanzenreste aus Ellesmere-Land. Rep. 2nd Norwegian Arctic Exped. in "Fram," 1898–1902, No. 35, 1915.

PAMPALONI, L. (1).—Microflora e Microfauna nel disodile di Melilli in Sicilia. Atti della Reale Acad. dei Lincei, ser. 5, XI, pp. 248–253, 1902.

PAMPALONI, L. (2).—I resti organici nel disodile di Melilli in Sicilia. Palaeontographia Italica, VIII, pp. 121–130, 1902.

THEISSEN, F. (1).—Die Gattung Asterina. Abhandl. k. k. zool.-bot. Ges. Wien, VII, 1913.

THEISSEN, F. (2).—Ueber Membranstructuren bei den Microthyriaceen als Grundlage für den Ausbau der Hemisphaeriales. Myc. Centralbl. III, pp. 273–286, 1913.

EXPLANATION OF PLATE VIII.

All the specimens are in the Geological Department, British Museum (Natural History). The photographs are by Mr F. W. Edwards.

Fig. 1. *Phragmothyrites eocaenica* sp. n. Group of thyriothecia. ×80. Slide V. 14847*a*.

Fig. 2. *Phragmothyrites eocaenica* sp. n. A single thyriothecium. ×380 (the largest observed). Slide V. 14847*a*.

Fig. 3. *Phragmothyrites eocaenica* sp. n. Another thyriothecium. ×380. Slide V. 14847*a*.

Fig. 4. *Phragmothyrites eocaenica* sp. n. Two thyriothecia at an earlier stage of development. ×380. Slide V. 14847*a*.

Fig. 5. *Phragmothyrites eocaenica* sp. n. A stigmocyst. ×540. Slide V. 14846*b*.

Fig. 6. *Phragmothyrites eocaenica* sp. n. Group of stigmocysts beginning to grow. ×540. Slide V. 14846*a*

Fig. 7. Presumed ascospore of *Phragmothyrites eocaenica* sp. n. ×540. Note the delicate hyphae at each end. Slide V. 14846*b*.

A SINGULAR CORDYCEPS FROM STEPHEN ISLAND, NEW ZEALAND.

By G. H. Cunningham, Wellington, N.Z.

At the north-west extremity of Cook Strait, about three miles from D'Urville Island, the nearest land, lies Stephen Island, a small area one and a quarter miles in length and rising to a height of 900 feet above sea level. The island is for the most part open tussock country with, in the more sheltered localities, a few isolated patches of wind-swept forest.

Although only 370 acres in extent Stephen Island rejoices in the possession of a somewhat unique fauna. Here are found the tuatara, *Sphenodon punctatus* Gray, which occurs in thousands and appears to be slowly increasing in number; *Deinacrida rugosa* Buller, a huge *weta*, found in only one other locality; a Discoglossid frog, *Liopelma hamiltoni* McCulloch, a recently discovered species confined to this island, where its habitat appears to be the crevices under large boulders; and a now extinct wren, *Traversia lyallii* Roths.

With the single exception of the *Cordyceps* described below, the flora possesses no peculiar features, as there are no endemic species.

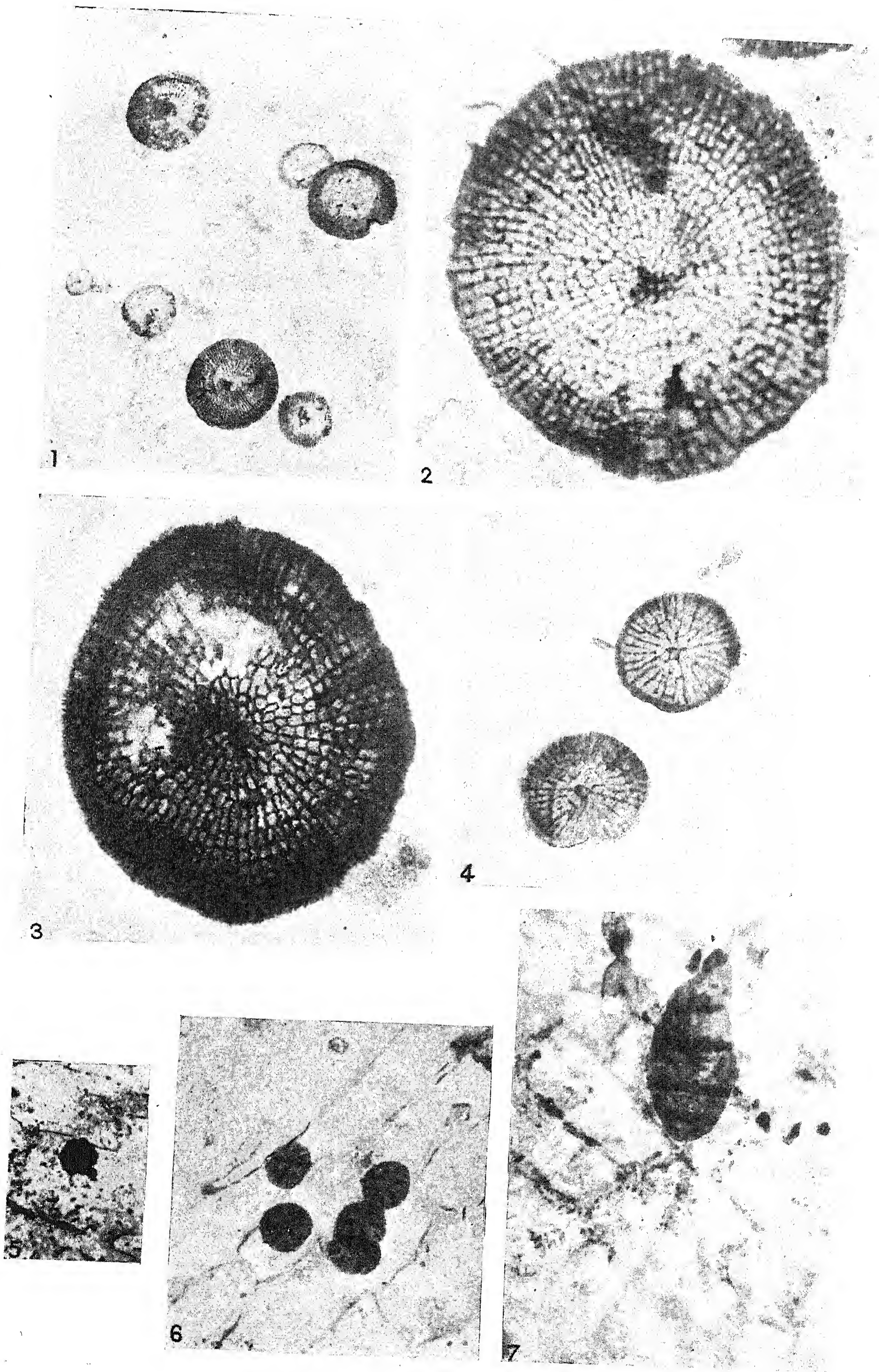
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FIG. 1.

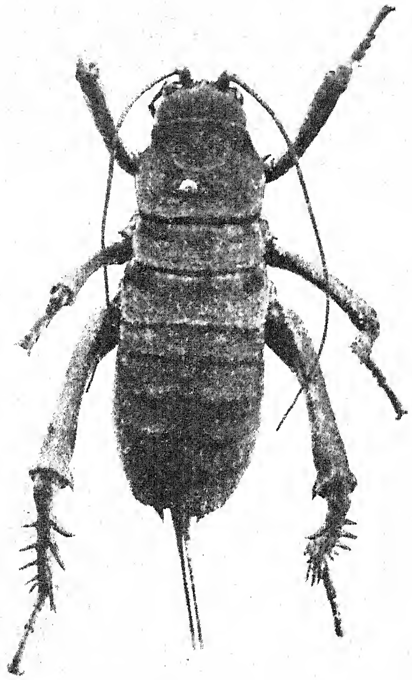


FIG. 2.

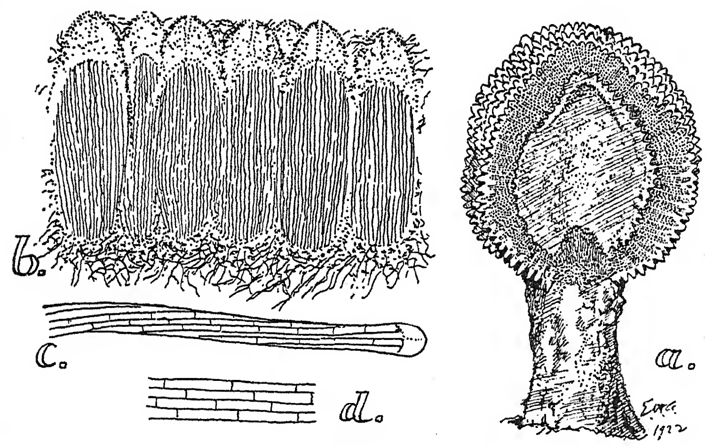


FIG. 3.

Fig. 1. Photograph of *Cordyceps Kirkii* sp.nov. showing gregarious stromata. About twice nat. size.

Fig. 2. Imago of *Deinacrida rugosa* Buller, female specimen. Nat. size.

Fig. 3, *a*. Section through fertile portion of stroma, showing arrangement of perithecia. ×6 diam.

b. Section showing superficial perithecia. Note thick apices of perithecia. ×30 diam.

c. Ascus showing capitate apex. *d*. Secondary spores. ×1000.

Photographs by E. Bruce Levy. Drawings by E. H. Atkinson.

The *Cordyceps* specimens referred to were found lying on the ground under stones by Professor H. B. Kirk whilst searching for *Liopelma hamiltoni* McCulloch.

This adds another species to the *Cordyceps* of New Zealand and brings the total up to six, of which no less than five are endemic. The others, together with an account of their hosts, have been discussed by the writer in a former paper published in the Transactions of the N.Z. Institute, LIII, 372 (1921).

I am indebted to Mr W. R. B. Oliver, of the Dominion Museum, Wellington, N.Z., for particulars regarding Stephen Island and its fauna and flora.

Cordyceps Kirkii sp.nov. (Illus.).

Conidial phase accompanying the perithecial, covering surface of host with a dense weft of mycelium, dingy cream, pruinose; conidia hyaline, elliptical, 3–6 × 1–1·5 μ.

Stromata gregarious, growing from intersegmental membranes of the body, and from knee joints, bases of antennae, eyes, and on femurs, stipitate, short, up to 6 mm. long; stem up to 4 mm. long, 1 mm. thick, dingy cream; fertile portion irregularly globose, ovate, or frequently angular, sometimes longitudinally grooved, 1·5–2 × 1·5 mm. diam., pallid brown.

Perithecia superficial, elliptical or elongate-oblong, obtuse, densely packed around a sterile central axis, pallid brown, 700–800 × 150–170 μ, apex thickened up to 120 μ, walls 20–25 μ thick. Asci hyaline, narrowly cylindrical, tapering from apex to base, terminating in a short clavate pedicel, not constricted below capitate apex, 165–210 × 5–6 μ. Spores in spirally twisted fascicles in asci, filiform, same thickness throughout, multiseptate, 80–120 × 1–1·5 μ, secondary spores not readily separable in asci, 6 × 1–1·5 μ.

HOST: Male and female imagines of *Deinacrida rugosa* Buller. Stephen Island, Cook Strait, New Zealand. H. B. Kirk. Jan. 1922.

I have named this species in honour of the collector, Prof. H. B. Kirk, Victoria University College, Wellington, N.Z.

NOTE ON THE HOST. By J. G. Myers.

Deinacrida rugosa Buller*.

This is one of the largest New Zealand species of the interesting Orthopterous family STENOPELMATIDAE, which is well represented in this country by more than thirty species distributed among twelve genera, and all characterised among other peculiarities by the complete absence of wings or elytra.

* Trans. N.Z. Inst. III, 36, 1871.

Under the Maori name of *weta*, and the extremely incorrect titles of "scorpion" or "scorpena," one or other of the commoner species is a familiar object to most people. The species under discussion belongs to an endemic genus. The type is said to have been discovered in an underground burrow at Wanganui; but the species is not now known to me to occur at any locality on the mainland. The two affected specimens, a female with numerous stromata, and a male, were taken under stones by Prof. H. B. Kirk at Stephen Island in Cook Strait where these huge *wetas* are still fairly common and form, in spite of their heavy armature of spines and plates, a portion of the food of the tuatara, *Sphenodon punctatus* Gray. The insect also occurs on Mana Island, and may possibly frequent other islets in Cook Strait.

Cordyceps Kirkii sp.nov.

Statuo conidiale cum statuo peritheciale, superficiem hospitis storea densa mycelii contegente, ravo-pallido-flavo, pruinoso; conidiis hyalinis, ellipticis, 3–6 × 1–1·5 μ.

Stromatibus congregatis, ex membranis intersegmentalibus corporis, et ex genibus, basibus antennarum et oculorum et in femoribus crescentibus; stipitatis, brevibus, ad 6 mm. longis. Stipite ad 4 mm. longo, 1 mm. crasso, ravo-pallido-flavo. Parte fertile inaequaliter globosa, ovata vel saepe angulifera, aliquando in longitudinem striata, 1·5–2 × 1·5 mm. crassa, pallido-brunnea.

Peritheciis externis, ellipticis vel elongato-oblongis, obtusis, dense confertis, pallido-brunneis, 700–800 × 150–170 μ; apice crasso ad 120 μ, muris crassis 20–25 μ. Ascis hyalinis, angusto-cylindraceis, pedicello breve clavato terminatis, infra apicem capitatam non constricto, 165–210 × 5–6 μ. Sporidiis in fasciculis tortuosis in ascibus, filiformibus, cylindraceis, multiseptatis, 80–120 × 1–1·5 μ; sporidiis secundariis non distinguendis in ascibus, 6 × 1–1·5 μ.

HAB.: in imaginibus *Deinacridae rugosae* Buller (Orthoptera). Stephen Island, Cook Strait, Nov. Zeal. H. B. Kirk. Jan. 1922.

THE STRUCTURE AND AFFINITIES OF LEUCONOSTOC MESENTEROIDES (CIENKOWSKY) VAN TIEGHEM.

By W. B. Crow, M.Sc., F.L.S., University College of South Wales and Monmouthshire.

The earliest records of bacteria of the type now known as *Leuconostoc* are of their occurrence as gelatinous masses in the vats containing sugar solutions in beet-sugar factories. These growths, which have been called "gomme du sucrerie" and "frog-spawn," were at first regarded as non-living transformation products of the cytoplasm of the beet itself, but their power of reproduction soon showed them to consist of living organisms. In 1878 Cienkowsky (2) described their microscopic appearance, gave them the name *Ascococcus mesenteroides* and placed them in the Bacteria near Cohn's *Ascococcus Billrothi* (now considered a species of *Micrococcus* (11)). He believed the organism to be very polymorphic and to exist in the cell-forms *Micrococcus, Torula, Bacterium, Bacillus* and *Vibrio*. In the same year van Tieghem (10) summarised earlier observations, examined Cienkowsky's material and also isolated the organism from fragments of dates and carrots. He found that many of the cell-forms noted by Cienkowsky were those of other organisms admixed and that the so-called frog-spawn itself was due to a single cell-type, a coccus occurring in chains or more often in groups of two. Van Tieghem also described the occurrence and structure of spores. In 1892 Liesenberg and Zopf (8) found that the organisms of European beet-sugar factories and those of Javanese cane-sugar works were identical in their morphology and had very similar physiological characters although they could be distinguished by slight differences in some of the latter. They grew both varieties in the absence of glucose and sucrose and found that under such conditions the colonies assume an entirely new form, lacking the gelatinous features of the original type. They failed to find any spores.

Very few researches on *Leuconostoc* have appeared in more recent years. The frog-spawn trouble in sugar-works is now, owing to new methods of procedure, much rarer, and where it occurs certain mucilage forming rod-bacteria are generally the cause, no doubt owing to the different conditions prevailing.

From the above-mentioned investigations, the main features of the organisation of *Leuconostoc mesenteroides* are well known, but in the present account attention may be drawn more particularly to certain characters which have a bearing upon the affinities of the plant and which previously have been overlooked. Only the typical species *Leuconostoc mesenteroides* (Cienk.) van Tieghem was studied. No doubt a number of allied species exist (6).

When grown in liquid media containing sucrose the colonies assume the form of rounded, slightly elongated, translucent, white masses, very variable in size but often over 1 cm. in length and 1·5 to 2 c.c. in volume. It is stated that under special conditions the individual masses may attain a much greater size than this, and may even occupy volumes of several hundred c.c. The colonies normally show a characteristic deeply folded or cerebriform surface which gives the plant its specific name. In cultures on some solid media (e.g. beet) they retain this character, but on others (e.g. various agars) this is less obvious and may be absent, the colonies tending to an amorphous form, especially on media which restrict the production of mucilage. The colonies of the sheathless form obtained by Liesenberg and Zopf are of course amorphous. Macroscopically the normal colonies can be distinguished clearly from those of certain rod-bacteria of similar mode of life and which form the so-called rice-grain of sugar-works.

The growth of these colonies is often extremely rapid. Under favourable circumstances a volume of forty-nine hectolitres of 10 % sugar solution was filled in the course of twenty-four hours with these spawn-like masses (4). Of course the great bulk of the organism depends on the mucilage and actual average measurements show this, in 10 % sugar solution, to occupy at least one hundred times the volumes of the protoplasts themselves. The same result is obtained if we compare the rate of growth of the colonies on media containing glucose with that on sugar-free media.

Reproduction of the colonies of *Leuconostoc* takes place very largely by vegetative breaking. The development of the colony from a single cell has been described by van Tieghem and by Liesenberg and Zopf. According to these authors the cell surrounds itself by a mucilage capsule and divides to form a filament. The capsule eventually gives place to a tubercular mass of numerous capsules so that a section of the thallus has a pseudoparenchymatous appearance. I find that this is well seen in preparations made with ordinary bacterial capsule stains (Friedlander, Welch). According to van Tieghem this segmentation of the capsules is due to the constriction of the

sheath of the original filament which becomes twisted and intertwined to form the colony.

The cells are generally all alike, being spherical and only 0·8–1·2 μ in diameter. The sheath in well-developed specimens is from 10–20 μ wide but may be less or not developed at all in which case we are dealing with the form *nuda* of Liesenberg and Zopf. I have not seen the large elongated cells as figured

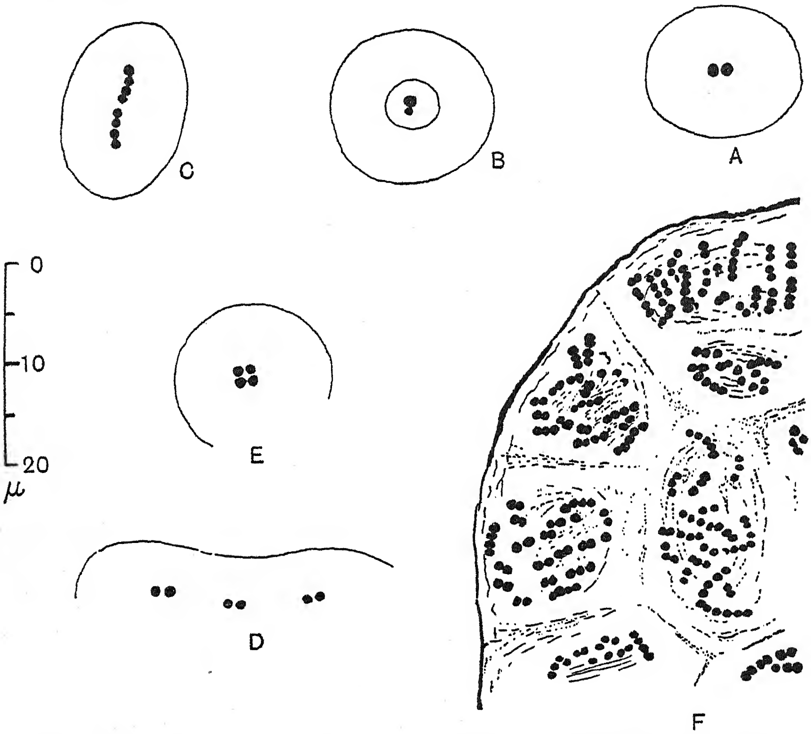


FIG. 1. A–E. Capsules detached from young colony. A. Typical form. B. Form with stratified membrane showing difference in size of cells. C and D. Forms showing filamentous tendency. E. Form showing cell-division in two planes at right-angles. F. Portion of section of colony showing capsules forming pseudoparenchymatous structure.

by Orla-Jensen (6) in his *Betacoccus bovis* but some strains included by him in this species may not be identical with *Leuconostoc mesenteroides*. On the other hand we may sometimes find one of a pair or one cell in a filament differing appreciably in size from the others. Such cells at first suggest arthrospores, but an examination of their behaviour towards stains shows them to be, in their reactions, quite normal cells. The latter

fact disposes of the suggestion that they might represent heterocysts such as are met with in the group of the Cyanophyceae. Whilst the structural characters of the cell-wall in spores and heterocysts and especially the pore and polar granule of the latter would be almost impossible to detect in such small cells as those of *Leuconostoc*, yet it must be remembered, that both the spores and heterocysts of Cyanophyceae have very definite staining reactions which distinguish them from vegetative cells.

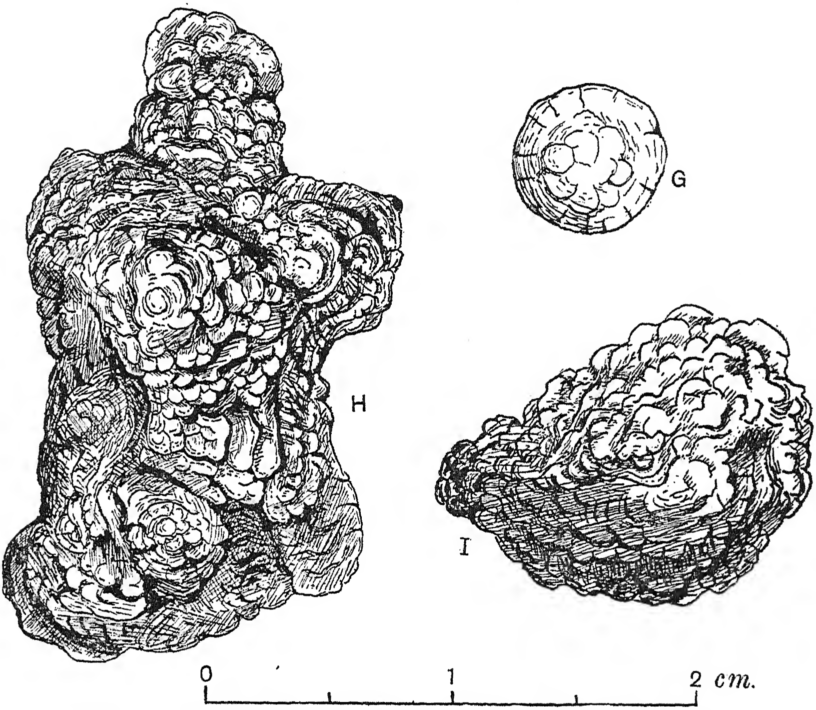


Fig. 2. G. Surface view of colony grown on 10 % sucrose-agar.
H and I. Surface view of colonies grown in sucrose solution.

Cell-division generally takes place in one direction only so that the cells form short filaments which, however, seldom reach more than eight cells in length before breaking up, and generally there is a considerable amount of mucilage produced between the successive divisions so that the cells appear in groups of two. Occasionally (or fairly frequently in the form *nuda*) tablets consisting of four cells are seen. This deviation from the normal method of division cannot be regarded as pathological as it occurs in healthy, rapidly growing cultures. As this is the case

such abnormalities may represent a previous phase in the phylogeny of the organism and thus tend to show *Leuconostoc* to be derived from forms, the cells of which divided in more than one direction. Certainly their appearance in an organism derived from typical filamentous ancestors would be difficult to account for.

With regard to the cell contents the extremely small size of the protoplasts is again an obstacle to their investigation. Many strains of *Leuconostoc*, if not all, are gram-negative (11). Beyond this it is only possible to state that neither starch nor glycogen have been detected by the iodine reaction, nor do the ordinary fat reagents give positive results.

The mucilage envelope therefore appears to represent the only material comparable with the solid metabolites seen in so many algae and fungi, and being produced directly from the cell cannot be considered as essentially different in morphological nature from these products. The membrane only develops when the organism is growing in media containing the sugars, sucrose or glucose. As the organism contains the enzyme invertin which decomposes sucrose into glucose it would seem probable that the latter is always the immediate source of the mucilage formation. In the fact that its envelope production is dependent upon a copious supply of hexoses, *Leuconostoc mesenteroides* differs very remarkably from the mucilage-forming algae. But this difference cannot be considered as of importance in relation to the systematic position of the organism since colourless representatives are met with in many algal groups and the situation with regard to mucilage production is the same in *Leuconostoc* as in many algae. In the Cyanophyceae, for instance, although the formation of envelopes is independent of the presence of sugars in the external medium this is because the organisms are autotrophic and in fact the formation of reducing sugars as an early stage in photosynthesis within the cells of many Cyanophyceae has been demonstrated by Gardner (5).

But from a systematic point of view the constitution of the membrane is more important than its original source, since its microchemical structure will depend upon the specific properties of the protoplasm of the organism. Like the cell-wall of the majority of organisms the envelope of *Leuconostoc* is not composed of a single chemical substance (7). This is shown by the work of Scheibler (7, 10) who boiled the gelatinous mass in calcium hydroxide solution and found only a small portion was dissolved. From the extract he obtained dextran which he therefore considered as one of the constituents of the membrane. But as Lafar (7) points out, this substance may be merely a

product of hydrolysis of the constituents. According to Benecke(1) the chief substance is formed by the coming together of several molecules of glucose and the loss of water. In its solubility in strong acids and alkalis the membrane shows a difference in constitution from that of many algae. An investigation of the microchemical reactions of the membrane gave the following results.

(*a*) Cellulose and schizophycose are absent. This is shown by tests with zinc chloriodide, iodosulphuric acid and the calcium chloride reagent of Mangin(9) and the insolubility in cuprammonia solution.

(*b*) Proteins and amino-compounds are absent. Negative results were given by the xanthoproteic reaction, by Millon's reagent and by haematoxylin, etc.(1).

(*c*) Pectins are absent. Observations were made with ruthenium red, safranin and methylene blue, all of which give characteristic reactions with pectic substances if neutral or slightly alkaline material be used(9). Control reactions with *Nostoc* and *Microcystis*, two algae having well-developed envelopes superficially similar to those of *Leuconostoc*, stained red with ruthenium red and, with safranin and methylene blue, gave bright orange and violet coloration respectively. On the other hand the material of *Leuconostoc* did not fix ruthenium and gave rose-red and blue colorations with safranin and methylene blue respectively.

(*d*) The mucilage of *Leuconostoc* has several of the reactions of callose, viz. insolubility in cuprammonia solution, staining reaction with anilin blue, corallin soda, negative reaction with zinc chloriodide and iodine. Unlike callose it does not stain with haematoxylin, is insoluble in dilute alkalis and is optically active.

The envelope is the most striking feature in the morphology of *Leuconostoc mesenteroides*. Structures of comparable form are met with in the Chroococcaceae and the Nostocaceae among the Cyanophyceae and in the Tetrasporales and Heterocapsales among the Isokontae and Heterokontae respectively. Many Cyanophyceae are partially saprophytic and that holosaprophytic members of the group might exist has long been suspected. It is now recognised that palmelloid types have developed independently along various lines of evolution. In *Leuconostoc* as in many other capsulated organisms, the envelope is not always present (f. *nuda*) and we have already referred to the variability in external form of the colonies. The mere possession of the envelope is, therefore, by itself, no criterion of affinity. Moreover, those algal envelopes which approach most closely in external form to that of *Leuconostoc* differ from the

latter in morphological construction. The envelope can be readily separated from the protoplasts, whilst in the Cyanophyceae violent plasmolysis is necessary to effect this. The breaking of the membrane into concentric layers is also a feature in which *Leuconostoc* differs from the Nostocaceae and the majority of other algae. Unlike the higher Cyanophyceae *Leuconostoc* possesses no individual cell-sheath. In this, as in its occasional cell divisions in two planes, *Leuconostoc* approaches the Chroococcaceae more closely than the Nostocaceae. On the other hand the chemical constitution of the envelope is not that of any of the Cyanophyceae, nor of the Tetrasporales or Heterocapsales. The chemical nature of the envelope is undoubtedly an important systematic character, being not only of specific value, since observations on *Leuconostoc mesenteroides* itself show the actual constitution of the envelope to be more constant than its form or degree of development, but also of much higher taxonomic importance in view of the fact that the nature of the membrane substance and of metabolites in general is distinctive in the wider groups (orders, classes) of Thallophyta.

In their report in 1920 on the classification of the bacteria a committee of the American Society of Bacteriologists (11) place the genus *Leuconostoc* in the tribe Streptococceae in the family Coccaceae. According to Orla-Jensen (6) *Leuconostoc*, which as already mentioned he includes in his genus *Betacoccus*, is to be placed in the lactic acid bacteria which embraces, besides many Coccaceae, a number of rod-forms.

Leuconostoc mesenteroides has often been associated with the genus *Streptococcus* and by some writers is included in the latter. The Gram-reaction may perhaps be a distinguishing feature, although the precise systematic value of this character is hard to estimate. It is not absolutely constant for given species amongst the Coccaceae. It might be suggested that the Gram-reaction in the cells of *Leuconostoc* would frequently be hindered by the presence of the secreted mucilage. But some Nostocaceae possessing equally developed envelopes on staining for comparison with *Leuconostoc* show the typical positive reaction. Incidentally it may be mentioned that the species of Cyanophyceae are very variable with respect to the Gram-reaction so that it has no importance as a group character.

The majority of species of *Streptococcus* are parasites, but there are considerable biochemical similarities between the two genera as has been shown by Orla-Jensen (6). The latter investigator has also shown that *Streptococcus* and, in fact, all the bacteria falling in his group of lactic acid bacteria produce capsules during the early stage of development of the colony. On the other hand *Leuconostoc*, in its sheathless form is quite

isomorphous with *Streptococcus*. There is thus no fast morphological distinction between the two genera, but they can be easily distinguished by the fact that the dominant phase in the life-history is different in the two cases.

The obvious affinity of *Leuconostoc* with *Streptococcus* does not enable one to connect the genus with autotrophic forms. In fact many of the species of *Streptococcus* appear to be more advanced both in their morphology and biochemistry. The parasitic habit of *Streptococcus* has already been referred to. The genus *Diplococcus*, which resembles *Leuconostoc* in its paired or sometimes seriate cells and in its frequent formation of capsules, is even more specialised chemically, "growing poorly or not at all on artificial media" (11). Morphological complexity is seen in the development of long chains of cells in some species of *Streptococcus* whilst the special larger cells, already referred to in *Leuconostoc*, are even more conspicuous here, although their nature does not appear to have been studied.

The envelope of *Leuconostoc* has already been noted as staining with the stains used for demonstrating those of bacteria. It thus reacts, on the methods of Friedlander and of Welch, in the same way as the capsule of *Diplococcus lanceolatus*. We have little information concerning the capsules of bacteria in general. The observations of Bräutigam show the gelatinose of *Micrococcus gelatinosus* to be similar to, if not identical with, the chief constituent of the envelope of *Leuconostoc*. On the other hand the presence of nitrogen compounds was established by Beijerinck in *Streptococcus hollandicus*, and Hamm found bacterial capsules consisting of protein (3). It would thus appear that, although we can trace no near affinity of *Leuconostoc mesenteroides* with the Cyanophyceae on the grounds of its membrane the latter differs still more remarkably from that of certain other bacteria and in its carbohydrate nature would seem to be relatively primitive.

The genus *Leuconostoc* is thus allied to certain bacteria and must be provisionally placed in the Coccaceae. A more detailed analysis of the systematic characters of the various other representatives of this family will, of course, be necessary before their phylogenetic relationships can be fully understood. That *Leuconostoc* may be a fairly primitive member of this plexus is suggested by the fact that its mode of life is not so highly specialised as that of the majority of the Streptococceae and by its palmelloid character which, by analogy with the algae, must be regarded as a more primitive stage of development than the filamentous. The capsulated forms in the young colonies of the higher Streptococceae thus appear as phases recapitulating the ancestral type. The resemblance of *Leuco-*

nostoc to the Chroococcaceae in certain characters as mentioned above appears to be due to the common palmelloid nature rather than close systematic relationship since we have seen that *Leuconostoc* differs from this family in many details of taxonomic importance. *Leuconostoc* certainly cannot be regarded as derived from the Nostocaceae or other filamentous algae. It is likely that the palmelloid character in this genus has had an independent phylogenetic development from that of other bacterial and algal types.

In conclusion the writer wishes to acknowledge the kindness of those who have sent him specimens of *Leuconostoc* and related organisms, or information respecting them. Thanks are particularly due to Col. Wall, J.P. of West Ham, Dr Ashby of Barbados and Prof. Van der Bijl of Stellenbosch.

LITERATURE.

(1) Benecke, W.—Bau und Leben der Bakterien, 1912.
(2) Cienkowsky, L.—Ueber die Gallertbildungen des Zuckerrübensaftes. Arbeit. d. Naturforscherges. a. d. Univ. zu Kharkow, xii, 1878.
(3) Czapek, F.—Biochemie der Pflanzen, i, Ed. ii, 1913.
(4) Fischer, A.—The structure and functions of Bacteria, 1900.
(5) Gardner, N. L.—Cytological Studies in Cyanophyceae. Univ. of Calif. 1906.
(6) Jensen, Orla-.—The Lactic Acid Bacteria. Danish Acad. Sci. 1919.
(7) Lafar, F.—Technical Mycology, i, 1898.
(8) Liesenberg, C. and Zopf, W.—Ueber den sogenannten Froschlaichpilz. Beitr. zur Physiol. u. Morphol. nieder Organismen, i, pp. 1–29, 1892.
(9) Tunmann, O.—Pflanzenmikrochemie, 1913.
(10) Van Tieghem, P.—Sur la Gomme de Sucrerie (*Leuconostoc mesenteroides*). Ann. Sci. Nat. 6th sér., Tom. vii (Bot.), pp. 180–203, 1878.
(11) Winslow, C.-E. A. and others.—The Families and Genera of Bacteria. Journ. Bact. v, 1920.

SOME OBSERVATIONS ON THE MYCOPHAGOUS PROPENSITIES OF SLUGS.

By W. T. Elliott, D.D.S., F.L.S., F.Z.S.

During the years 1917–1920 the following observations were made in order to try and establish any fact showing that some species of slugs are more attracted by fungi as food than others, and to ascertain whether slugs have a preference for any particular fungi. This subject does not appear to have received much attention. Gain (1891) made an extensive series of observations on the food of mollusca generally, but only refers to ten species of fungi. He found that *Boletus edulis* is eaten with avidity by *Arion ater* and *Limax maximus*, that *Polyporus squamosus* is scarcely touched by *Arion hortensis*, *Agriolimax agrestis* and *Limax arborum*, whereas *Agriolimax agrestis* is

stated to attack not only *Boletus edulis*, but also *Amanita muscaria* and *Amanita phalloides*, apparently avoiding *Boletus luridus* (see Turton, p. 81).

The method I adopted was to keep from three to six of each species of slug under an inverted glass bowl that accurately fitted a saucer, in which either moss or earthy soil was placed, and the fungus either whole or cut to a suitable size was introduced, and allowed to remain for forty-eight hours. At the end of this period it was removed and the amount and parts that had been eaten duly noted. The slugs were not fed again for three days at least, before any other food was tried. The results as to preference for any particular part of the fungus show that sometimes the stipe was first attacked and in other cases the hymenium or the pileus, but they are as yet incomplete and require further confirmation, so that they are not given in the table herewith.

The following remarks may be made concerning the ten species of slug that have been used for the experiments.

Arionidae.

1. *Arion ater* is extremely voracious and omnivorous. It will devour decomposing or living animal matter and also its own fellows, in fact, almost anything, paper, or sand (Cooke, p. 31), also the poisonous berries of *Arum maculatum*, as well as poisonous fungi such as *Amanita pantherina*.

2. *Arion subfuscus* usually prefers non-chlorophyllaceous material as its food, as also does *Arion intermedius* and *Limax maximus*, hence, as would have been anticipated, these species possess a great partiality for fungi. Taylor (p. 196), referring to *A. subfuscus*, says that *Phallus impudicus* was greedily devoured, but the animals died soon afterwards.

3. *Arion circumscriptus* is a geophilous slug, and, so far as my observations go, does not appear to be very partial to fungus food, yet it may often be found in the stipe and pileus of many Agarics.

4. *Arion intermedius*, known as the hedgehog slug, is apparently purely mycophagous. It frequents uncultivated ground where fungi abound, and refuse where fungoid growths are developing.

5. *Arion hortensis* is another geophilous species, and is a chlorophyll feeder, being rarely found on fungi: it does not apparently seek fungi for food, but I have observed that it devours three species of Russula with avidity.

Limacidae.

6. *Limax maximus* is an omnivorous feeder, having a partiality for kitchen refuse, such as fat, meat scraps, and milk, but it avoids those substances that contain chlorophyll. It has

cannibalistic propensities and its preference for fungus food is very marked.

7. *Limax cinereo-niger* is mainly mycophagous, its habitat being woods and forests where fungi abound. Stahl records that the food of this species was apparently solely fungi, as the excrementious matter was composed of partially digested hyphae and undigested spores (Taylor, p. 57). Prof. Buller (1909, p. 226) refers to the experiments by Voglino upon the dispersal of spores of Hymenomycetes by slugs and the conclusions may be that they do not materially exert much influence in that direction.

8. *Limax arborum* feeds exclusively on lichens. In three instances, however, it slightly tasted fungi (see table). I have kept this species for some months in captivity, when it refused food of any kind beyond what could be obtained from the dead wood in the cage. Its habitat being arboreal, it probably has changed its diet from fungi to lichens (see Taylor, p. 93).

9. *Milax sowerbyi* is not at all partial to fungi and has only eaten this food under compulsion.

10. *Agriolimax agrestis*, the common field slug, is exceedingly partial to chlorophyllaceous food, as all farmers and gardeners can testify, it being very destructive. Its olfactory sense for chlorophyll is very marked, for it quickly finds young seedling plants, which it greedily devours. Still, at the same time, it will readily devour certain fungi, earthworms and insects, and as a feeder is very similar in its propensities to *Arion ater*. Its habitat is variable and its food is just as varied. Taylor (p. 108) says that it is not usually a fungus eater, but at times feeds upon various kinds, both poisonous and edible, such as *Amanita muscaria*, *Boletus edulis*, etc.

It is very evident, therefore, that some species have a marked taste for chlorophyll food although no slug actually favours it entirely. On the other hand, *Arion subfuscus*, *A. intermedius*, *Limax maximus* and *L. cinereo-niger* are decidedly mycophagous, but will eat chlorophyllaceous food under compulsion. Slugs in comparison eat very much more food than snails; obviously the reason being to repair the great waste from the excessive muscular action required in moving to and fro to cover and safety. It is seldom that we find a large fungus that has not been attacked by a slug and also it is seldom one finds more than one animal on the fungus, but it rarely happens as at 5 a.m. on an October morning (22. x. 16) with the sun rising and light fleecy clouds in the sky, and with the sheep tracks showing a heavy dew, that Puff-balls, Liberty Caps and Mushrooms in abundance were to be seen quite clean and not touched by a single slug.

Sense of Smell.

The olfactory sense is very highly developed in the mollusca generally, and is of more value to them than sight. Most authorities regard this sense as being situate in the tentacles. Moquin-Tandon (1851) made experiments by removing the tentacles, and he was satisfied that the animal then lost this sense or nearly so. Sochaczewer (1881) located this sense in a pedal gland near the mouth. Simroth (1882) says that it is distributed over the entire soft integument, as well as being concentrated in the tentacles, and near the respiratory orifice (Cooke, p. 192). Many experiments are recorded showing how acutely perceptive these animals are with the olfactory sense in the matter of food, but especially so with fungi.

Buller (1922) recorded an interesting series of observations he had made with *Limax maximus* and *Phallus impudicus*. He observed that the former found its way back many times to the Phallus by its sense of smell, even when removed from it to a considerable distance.

Blood and Nervous System.

Molluscan blood generally is colourless and devoid of red corpuscles. Haemoglobin as found in the blood of vertebrates is not present except in a few cases, for mollusca do not require great facilities for oxidisation, since being otiose, it is not necessary for the oxygen to be generally diffused. Haemocyanin, an albuminoid containing copper, largely replaces this haemoglobin. Its functions are similar, but less effective. Haemoglobin, however, is present in the buccal tissues of some species, since this is a part where energetic action is called for, also white corpuscles or amoebocytes occur much resembling those found in man (see Cooke, p. 171). This variation in the composition of the blood, as compared with that of man, may account for the fact that phallin, a solvent of red blood corpuscles, an alkaloid which is found in fungi, and poisonous to man, has no toxic effect on slugs. Muscarin, also, another alkaloid present in fungi producing a toxic effect on man since it causes paresis of the heart's action, is without effect on slugs because of their simpler nervous system; for these animals do not possess anything analogous to the sympathetic system in man which controls the heart's action; or it may be, these alkaloids are not absorbed by the molluscan tissues, and pass out through the alimentary tract.

The conclusions that may be deduced from these experiments below are:

1. *Arion ater*, *A. intermedius* and *Limas maximus* are extremely

partial to fungus food, that *Limax arborum* is not a fungus eater, and that *Agriolimax agrestis* has no partiality for this food.

2. The so-called poisonous and non-poisonous fungi have no relative effect upon slugs, although *Coprinus micaceus* killed those slugs left with the decomposing material, and *Arion ater* upon two occasions died after devouring with avidity *Russula emetica.*

3. Those fungi possessing cystidia, such as *Inocybe rimosa* and *Pluteus cervinus* are readily eaten. Buller (1909, p. 18) states that the significance of cystidia does not appear to have been elucidated with any certainty. Possibly in some cases they serve to protect the fruit bodies from slugs or other animal parasites. In certain Russulae they do not seem to render the gills unpalatable to slugs since the species of this genus are invariably attacked by them, although we find in the case of green plants that prickly or hairy investments and hard siliceous material are a protection against molluscan teeth. Cultivated plants generally in this respect being not so adequately protected are more readily attacked. Those species of Graminaceae, Equisetaceae and Cyperaceae, where minute acicular crystals of calcium oxalate are present, act as an irritant in the mouth of mollusca.

4. The chemical defences in green plants, such as acrid juices, alkaloids, nauseous secretions, etc. are a deterrent against slugs, yet fungi containing alkaloids such as Amanitae and acrid juices such as Russulae are not avoided. However, certain fungi having a viscid exterior such as *Gomphidius viscidus* and *Hebeloma mesophaeum* are refused, yet the viscid *Stropharia aeruginosa* is devoured. Buller (*l.c.*) says that the presence of nauseous or distasteful substances in the cellular structure appear to be protective against slugs.

5. Slugs are partial to all the species of Russulae and the poison that affects man has quite a diverse effect by reason of the chemical or physiological constitution of the blood and the simplicity of the nervous system.

6. They refuse tough and hard fungi, such as *Scleroderma vulgare* and *Panus stypticus*. Johnson (1920) says of *Panus stypticus* "one of the many fungi eaten by slugs: they cause the rapid disappearance of young sporophores and bite large pieces out of mature ones." This refers to natural conditions.

7. In conclusion, there appears to be no special property in fungi that makes them objectionable, or, on the other hand, that makes them attractive as food. Buller (*l.c.*) gives the results of experiments with three species of slugs, viz. *Limax maximus*, *Arion subfuscus* and *Agriolimax agrestis*, upon twelve species of fungi and these generally agree with those in the appended table.

Experiments with 60 *species of fungi.*

E = Eaten entirely or with avidity.
S = Slightly eaten.
N = Not touched or refused.

	Experiments	E	N	S
Arion ater	24	13	2	9
,, subfuscus	20	4	4	12
,, circumscriptus	2	—	—	2
,, intermedius	2	2	—	—
,, hortensis	13	5	4	4
Limax maximus	42	21	7	14
,, cinereo-niger	35	16	7	12
,, arborum	9	—	6	3
Milax sowerbyi	8	—	3	5
Agriolimax agrestis	15	1	10	4
	170	62	43	65

	Mixed slugs	Arion ater	A. subfuscus	A. circum-scriptus	A. intermedius	A. hortensis	Limax maximus	L. cinereo-niger	L. arborum	Milax sowerbyi	Agriolimax agrestis
Amanitopsis vaginata	E	E	—	—	—	—	—	—	—	—	—
Amanita pantherina	—	S	—	—	—	—	S	N	—	—	—
Boletus flavus	—	—	S	—	—	S	S	S	—	—	S
,, chrysenteron	—	—	—	—	—	—	S	—	—	—	—
,, luridus	S	—	—	—	—	—	E	—	—	—	—
,, lactifluus	—	—	—	—	—	—	—	E	—	—	—
Coprinus micaceus	—	—	—	—	—	—	S	E	N	S	—
,, niveus	—	E	—	—	—	—	N	N	—	—	—
Craterellus cornucopioides	—	—	—	—	—	—	—	—	S	—	—
Collybia dryophila	—	—	—	—	—	—	—	N	—	—	—
,, platyphylla	—	—	S	—	—	—	E	—	—	—	—
,, esculenta	—	—	—	—	—	—	—	E	—	—	—
Clitopilus prunulus	—	S	—	—	—	—	N	S	S	S	N
Cortinarius purpurascens	—	—	—	—	—	E	—	—	—	—	—
Entoloma lividum	—	—	—	—	—	E	—	—	—	—	—
Galera hypnorum	—	—	—	—	—	—	E	E	—	—	—
,, tenera	N	E	—	—	—	—	—	—	—	—	—
Gomphidius viscidus	—	S	—	—	—	—	S	—	N	—	—
Hypholoma epixanthum	—	—	—	—	—	—	S	S	—	—	—
,, fasciculare	—	E	S	S	—	S	E	S	N	—	S
,, sublateritium	—	E	—	—	—	—	—	—	—	—	—
Hygrophorus psittacinus	—	—	S	—	—	N	E	E	—	—	N
,, puniceus	—	—	—	—	—	—	S	S	—	—	—
,, coccineus	—	—	—	—	—	—	—	N	—	—	—
,, pratensis	—	—	—	—	—	—	—	S	—	—	—
,, virgineus	—	—	—	—	—	—	—	S	—	—	—
Hebeloma fastibile	—	—	—	—	—	—	E	E	—	—	—
,, mesophaeum	—	E	S	—	—	—	S	E	N	N	N
Inocybe rimosa	—	—	—	—	—	—	E	—	—	—	—
Laccaria laccata	—	E	S	—	—	S	E	E	—	—	S
Lepiota granulosa	—	E	S	—	—	—	S	S	—	N	N
Lactarius deliciosus	N	E	N	—	—	—	S	—	—	—	—
,, rubra	S	S	—	—	—	—	S	S	—	—	—
,, quietus	E	—	—	—	—	—	S	—	—	—	—
,, subdulcis	S	—	—	—	—	—	S	—	—	—	—
Marasmius epiphyllus	—	—	N	—	—	N	—	N	—	—	N

	Mixed slugs	Arion ater	A. subfuscus	A. circumscriptus	A. intermedius	A. hortensis	Limax maximus	L. cinereoniger	L. arborum	Milax sowerbyi	Agriolimax agrestis
Mycena galericulata	S	E	E	S	—	—	E	S	—	—	N
,, sanguinolenta	—	—	N	—	—	N	E	E	—	—	N
Naucoria escharoides	—	E	—	—	—	—	E	—	—	—	—
Panaeolus campanulatus	—	—	—	—	—	—	S	N	—	—	—
,, papilionaceus	S	—	S	—	—	—	E	—	—	—	—
Pholiota squarrosa	—	—	—	—	—	S	—	E	—	S	—
,, terrigena	—	E	—	—	—	—	E	E	N	S	—
,, aurea	—	—	—	—	—	—	N	—	—	—	—
Polyporus sulphureus	—	—	S	—	—	—	E	—	—	—	—
Polystictus versicolor	S	—	—	—	—	—	N	—	—	—	—
Paxillus involutus	—	N	—	—	—	—	N	—	—	—	—
Panus stypticus	—	S	S	—	—	—	N	S	—	S	N
Pleurotus ostreatus	—	—	—	—	—	—	E	—	—	—	—
Psalliota arvensis	—	—	—	—	—	—	—	S	S	—	—
Pluteus cervinus	—	S	—	—	—	—	E	E	—	—	—
Russula cyanoxantha	E	E	S	—	—	—	E	—	—	—	—
,, subfoetens	—	—	—	—	—	E	E	E	—	—	—
,, rubra	—	S	E	—	E	—	—	—	—	—	—
,, fragilis	—	—	—	—	—	E	—	—	—	—	—
,, emetica	—	E	E	—	E	E	E	E	—	—	E
Scleroderma vulgare	—	—	N	—	—	N	N	N	—	—	N
Stropharia aeruginosa	—	—	—	—	—	—	E	E	—	—	N
Tricholoma personatum	—	S	S	—	—	—	E	E	N	N	S
Ulocolla foliacea	—	S	—	—	—	—	—	—	—	—	—

LITERATURE.

BULLER, A. H. R.—Researches on Fungi (1909).

—— Slugs as Mycophagists. Trans. Brit. Mycol. Soc. VII, pp. 270–283 (1922).

COOKE, A. H.—Molluscs in The Cambridge Natural History, III (1895).

GAIN, W. A.—Notes on the food of some of the British Mollusks. Journ. Conch. VI, Nos. 10 and 11, pp. 349–361, 1891.

JOHNSON, M. E. M.—On the biology of *Panus stypticus*. Trans. Brit. Mycol. Soc. VI, pp. 348–352 (1920).

MOQUIN-TANDON, A.—Mémoire sur l'organe de l'odorat chez les Gastéropodes. Ann. Sci. Nat. Zool. 3 sér. XV, pp. 151–158 (1851).

SOCHACZEWER, D.—Das Reichorgan der Landpulmonaten. Zeits. wissenschaft. Zool. XXXV, pp. 30–46 (1881).

TAYLOR, J. W.—Monograph of the Land and Freshwater Mollusca of the British Isles (1902–7).

TURTON, W.—A Manual of the Land and Freshwater shells of the British Islands, Ed. III (by J. E. Gray), 1857.

PRELIMINARY LIST OF MANITOBA FUNGI.

By G. R. Bisby and A. H. R. Buller.

Manitoba extends north of Minnesota and North Dakota from the 49th to the 60th parallels of latitude. Manitoba is, therefore, in the same latitude as the British Isles, and extends, roughly, from the parallel of Paris and Vienna to that of Christiana and Petrograd. Climatic conditions are quite different, however, from those of most of the corresponding area in Europe.

Many species of Phanerogams attain their northern limits in Manitoba, and various plants reach their eastern or their western limits in this province, which marks a transition from a wooded rocky region in the eastern part to drier plains in the western portion. Manitoba is a region of considerable mycological interest.

This list is very incomplete: in only a few groups, such as the rusts and polypores, has anything more than a general preliminary survey been made, and in no case can this list purport to approach completeness. It does, however, serve to extend the range for a considerable number of species of fungi, and records the occurrence of such fungous diseases as have been observed, especially during 1920 and 1921, in the province. The collections have practically all been made in the southern quarter of the province, and principally below the 51st parallel. One trip was made to the Swan River Valley, just above 52° north latitude. The fungi of eastern Manitoba are represented largely by collections from Kenora and Minaki, which are in Ontario, but near the Manitoba line, and which are representative of conditions in south-eastern Manitoba. The highly interesting far north of Manitoba is as yet little surveyed for fungi.

This list to a considerable extent is dependent upon, and its accuracy is greatly heightened by, determinations made by various specialists. Grateful acknowledgment is made to those who have determined or corroborated the determinations of various specimens, and also to Professor V. W. Jackson, Mr I. L. Conners (marked "I.L.C."), and others who have aided in making collections, and in determining hosts. The initial of those who have made determinations of fungi is given in each case: if no initial follows, the identification is by the writers. The key to these initials is as follows:

Br. = Dr J. F. Brenckle, Kulm, N.D. Pyrenomycetes, etc.
B. = Dr E. A. Burt, Missouri Botanic Gardens, St Louis, Mo. Thelephoraceae, etc.

D. = Dr J. J. Davis, Univ. of Wisconsin, Madison, Wis. Parasitic fungi.
E. = Dr W. T. Elliott, Arden Grange, Tanworth-in-Arden, Warwickshire, England. Myxomycetes.
F. = Prof. W. P. Fraser, Univ. of Saskatchewan, Saskatoon, Sask. Rusts, etc.
J. = Prof. H. S. Jackson, Purdue Univ., Lafayette, Ind. Certain Rusts and Smuts.
K. = Dr C. H. Kauffman, Univ. of Mich., Ann. Arbor. Mich. Certain Agaricaceae.
L. = Miss G. Lister, Leytonstone, England. Myxomycetes.
Ll. = Mr C. G. Lloyd, 309, W. Court St., Cincinnati, Ohio. Various Hymenomycetes.
V. = Dr L. O. Overholts, State College, Pa. Polypores, etc.
S. = Dr F. J. Seaver, New York Botanical Gardens, New York City. Certain Ascomycetes.
W. = Miss E. M. Wakefield, Kew Gardens, Surrey, England. Various fungi.

In addition to these, other specialists whose names are given have determined certain species.

Specimens from 500 to 1000 inclusive are at the University of Manitoba; other numbers are at the Manitoba Agricultural College. Where no locality is cited, Winnipeg or its environs is to be understood. Where no collector's name is given, one or the other of the writers made the collection; the number indicates which one. Thus, "Arcyria occidentalis Lister, 673*L*, 343*E*" means that both specimens were collected at Winnipeg, No. 673 by A. H. R. Buller, part of the collection being sent to Miss Lister, who made the determination; the remainder is filed at the University of Manitoba. No. 343 was collected by G. R. Bisby, and part of it sent to Dr Elliott, who furnished the name, the remainder being deposited at the Manitoba Agricultural College. It was not considered necessary to include dates of collection unless they were out of the ordinary. Collections from the Swan River Valley were made on July 1st to 13th, 1921; from Gilbert Plains and Ste. Rose du Lac and vicinity, July 25th to 31st, 1921. Collections from Minaki and Kenora have been made principally in September and October, and by A. H. R. Buller unless otherwise noted.

Where no number is given in connection with a species the specimen is not preserved, but its authenticity is considered reasonably accurate, unless a question-mark is appended.

This list is believed to cover nearly all the species of fungi that have ever been collected in Manitoba. The writers have gone over the list of the Manitoba fungi which are at Ottawa and have checked over the rust and smut portions of the North American Flora as well as certain other publications which might contain references to fungi from Manitoba. Apart from the collections of the writers and Messrs Fraser, Conners, and V. W. Jackson, probably few collections of fungi from this province have been made. Various references to Canadian fungi were checked, but in practically every case no collections had

been made in Manitoba, except in the case of Professor Macoun's list of lichens. References to various Manitoba fungi are, however, given in "Researches on Fungi" and other papers by A. H. R. Buller.

The nomenclature used varies somewhat: Dr Kauffman was followed for names of Agarics, Dr Overholts for Polypores, and Saccardo for many fungi. In general the writers have endeavoured to use the standard names for the fungi included. The names of hosts are taken largely from Britton and Brown's Flora.

Dr Davis has furnished the description of a new Cercospora for this list, and Mr Lloyd has considered a Ptychogaster sent him to be a new form. Two or three species are recorded for the first time for North America. In almost every case, however, the fungi found were those which had already been described for North America. Further and more critical search will of course extend this list, and the writers believe that a survey of Northern Manitoba will reveal a number of interesting fungi.

This list contains 574 fungi, as follows: Myxomycetes 34, Bacteria 8, Phycomycetes 20, Ascomycetes 62, Imperfect fungi 38, Smuts 20, Rusts 80, Polypores 63, Agarics 108, Thelephoraceae 36, other Basidiomycetes 57, Lichens 48.

MYXOMYCETES.

Parasitic species have not been found in Manitoba.

Acrasieae: Dictyostelium mucoroides Bref., observed by A. H. R. B.
Exosporeae: Ceratiomyxa fruticulosa (Muell.) Macbr., 326*E*., 1111, twice found in abundance on old wood.
Endosporeae: Arcyria denudata (L.) Wettst., 674*L*.
A. incarnata Pers., 658*E*.
A. incarnata var. fulgens Lister, 675*L*.
A. occidentalis Lister, 343*E*., 645*E*., 673*L*.
A. stipata Lister, 1241*L*., 1242*L*.
Badhamia macrocarpa (Ces.) Rost., 659, 660.
B. panicea (Fr.) Rost., 643*E*.
Comatricha irregularis Rex., Carman, A. R. Skinner, 676*L*.
Craterium leucocephalum (Pers.) Dittm., 340*E*.
Diderma globosum Pers., 646*E*., 647, 677*L*., 1179*L*.
D. spumarioides Fr., fruiting on grass and leaves, 1245*L*., 1246*L*.
Didymium melanospermum (Pers.) Macbr., 1249*L*.
D. squamulosum (A. and S.) Fr., 665, 782, 341*E*
Enteridium Rozeanum (Rost.) Wing, 656*E*.
Fuligo septica (L.) Gmel., 357*E*., 522, 648, 649, 780, 781.
F. septica var. candida Pers., 1247*L*.
Hemitrichia clavata (Pers.) Rost., 663, 657, 783*E*., 1240*L*., 1243*L*.
H. Vesparium (Batsch) Macbr., 678*L*.
Lamproderma violaceum (Fr.) Rost., Victoria Beach, 963*L*.
Lycogala epidendrum (L.) Fr., 345*E*., 620, 653, 654, 655, Swan River, 1035. Very common.
Mucilago spongiosa (Leys.) Morg., 342*E*., 767, 775, 779, 1250*L*.
Perichaena corticalis (Batsch) Rost., 426*L*.
Physarum auriscalpium Cke., 344*E*.
P. connatum (Peck) Lister, 651*E*., 679*L*., 1244*L*., 1248*L*. Common.

P. contextum Pers., 680*L*.
P. didermoides (Ach.) Rost., 664, det. Cheesman.
P. nutans Pers. var. leucophaeum Lister, 1243*L*.
P. sinuosum (Bull.) Weinm., 681*L*.
Stemonitis fusca Roth., 304, 644, 618, 683*L*. Common.
Trichia contorta Rost. var. inconspicua Lister, det. *E*. No specimens at Winnipeg.
T. persimilis Karst., 652*E*.
Tubifera ferruginosa Gmel., det. *E*. No specimens at Winnipeg.

BACTERIA.

These few species have been found as plant parasites in Manitoba. Other forms of course occur, but in general bacterial diseases of plants seem to be comparatively indestructive here.

Bacterium translucens J. J. and R., on Hordeum vulgare, 235. Collected and determined by I. L. Conners.
B. translucens var. undulosum S. J. and R. Black chaff is occasional on Triticum aestivum.
Bacillus amylovorus (Burr.) de Toni, on Pyrus Malus, 1099. Quite abundant in 1921.
B. atrosepticus v. Hall, on Solanum tuberosum, 224. A rather serious disease in wet and cool years. Not abundant in 1921.
B. carotovorus Jones, on celery, cabbage and other vegetables.
Pseudomonas Phaseoli E. F. Sm., on Phaseolus vulgaris, causing some loss, 471, 1084.
P. radicicola (Bet.) Moore, on various legumes, 794, 795; wherever legumes grow.
Bacterial Spot on Sudan grass at Winnipeg (Bacillus Sorghi Burr.?), 1153*D*.

PHYCOMYCETES.

None of the Phycomycetes has been found to cause any particular damage to agricultural crops. *Phytophthora infestans* is conspicuous by its absence.

Albugo Bliti (Biv.) O. Kuntze, on Amaranthus retroflexus, 128.
A. candida (Pers.) O. Kuntze, on Brassica sp., 188; on Raphanus sativus, 170.
A. Tragopogonis (DC.) S. F. G., on Cirsium arvense, Ste. Rose, 1169*D*.
Basidiophora Kellermanii (E. and H.) Wilson, on Iva xanthifolia. Reported by W. P. Fraser at Dauphin and elsewhere.
Cladochytrium Alismatis Buesg., on Alisma subcordata, coll. R. Broadfoot, det. I. L. C.
Empusca Muscae Cohn. On house fly, 356.
Mucor Mucedo (L.) Bref., Winnipeg, A. H. R. B.
M. racemosus Fres., A. H. R. B.
Peronospora effusa (Grev.) Rbh. (?). On Chenopodium album, coll. I. L. C.
P. Trifoliorum de By., on Medicago sativa, Brandon, I. L. C., 1154.
Plasmopora Halstedii (Farl.) Berl. and de Toni, on Ambrosia artemesifolia, Ste. Rose, 1134*D*.
P. obducens Schroet., on Impatiens biflora, Swan River, 1140*D*.
Phycomyces nitens (Agardh) Kunze, A. H. R. B.
Pilobolus longipes van Tiegh., on dung, A. H. R. B.
P. crystallinus (Wigg.) Tode, on dung, A. H. R. B.
Piptocephalis Freseniana de By., A. H. R. B.
Rhizopus nigricans Ehr. Common, sometimes semiparasitic on stored vegetables, etc.
Saprolegnia sp. on fish, etc.
Sporodinia grandis Link, on Lentinus lepideus, I. L. C., 1097.
Synchytrium decipiens Farl., on Amphicarpa monoica, 116, Morris, I. L. C., 109. Common.

ASCOMYCETES.

Saccharomycetales: Saccharomyces sp. in fruits of Prunus sp. (wild plum), 1208. Other "wild" yeasts also occur.
Protodiscales: Exoascus Pruni Fcl., on Prunus spp. 305, 325, Dominion City, 578. Common on plums.
Helvellales: Gyromitra esculenta (Pers.) Fr., Kenora.
Helvella crispa (Scop.) Fr., Gimli, 640, 764.
H. lacunosa Afzel., Russell, 1093.
Leotia lubrica (Scop.) Pers., Kenora, A. H. R. B.
Morchella esculenta (L.) Pers., 322, 393, 444, 439. Common.
M. conica Pers. (probably only a form of M. esculenta); Hillside Beach, 411
M. crassipes (Vent.) Pers., 788; Hillside Beach, 410; Minaki.
Spathularia clavata (Schaeff.) Sacc., Minaki, A. H. R. B.
Verpa conica (Mill.) Swartz, Hillside Beach, 409.
Pezizales: Ascobolus immersus Pers., on dung, Winnipeg, A. H. R. B.
Cenangium furfuraceum (Roth) de Not., 734*B*.
C. populneum (Pers.) Rehm, 919*S*.
Chlorosplenium aeruginosum (Oed.) de Not., Shoal Lake S.E. Man., I. L. C., 432; Kenora, 551, 711.
Coryne? sp., near Kenora, 911*S*.
Helotium citrinum (Hedw.) Fr., 384*S*., 407*S*., 1167*Ll*., 916, 926; near Kenora, 912*S*.
Lachnea scutellata (L.) Gill., Kenora, A. H. R. B.
Mollisia cinerea (Batsch) Karst., 401*S*., 420*S*.
Orbilia sp., 910*S*.
Peziza aurantia Muller, Minaki, 863.
P. badia Pers.? Hillside Beach, 412.
P. vesiculosa Bull., 363, 765.
Pseudospeziza Medicaginis (Lib.) Sacc. on Medicago sativa (cult.), 296; Brandon I. L. C., 1155; Swan River, 485.
Sclerotinia libertiana Fcl. on carrots, parsnips and other vegetables. What is considered to be this species has also been collected on Helianthus annuus (cult.), 609, causing a serious stem rot, and on Iva xanthifolia, 102, Cirsium arvense, Helianthus tuberosus, and Sonchus arvense.
Phacidiales: Propolis faginea (Schrad.) Karst., near Kenora, 913*S*.
Rhytisma salicinum (Pers.) Fr., on Salix sp., 90; Gilbert Plains, 1061.
Hysteriales: Hysterographium Fraxini (Pers.) de Not., on Ash wood, 1101*Br*.
Aspergillales: Aspergillus herbariorum (Wigg.) Fisch. Common.
Penicillium spp. The usual blue moulds on various substances.
Perisporiales: Dimerosporium Collinsii (Schw.) Thuem., on Amelanchier alnifolia, 820. Common.
Erysiphe Cichoracearum DC., on Helianthus annuus (cult.), 307; on Ambrosia trifida, Morris, I. L. C., 103.
E. Galeopsidis DC., on Stachys sp., Ste. Rose, 1070.
E. Graminis DC., on Secale cereale, 135. Not serious.
E. Polygoni DC., on Polygonum aviculare, 174, 300; Virden, 289; Swan River, 477; on Pisum sativum (cult.), 1087.
Microsphaera Alni (Wallr.) Wint., on Quercus macrocarpus, J. J. Christensen and G. R. B., 308.
M. diffusa Cke. and Pk. On Lathyrus odoratus, 288. Common.
Podosphaera Oxyacanthae (DC.) de By., on Prunus pumila, Dauphin, F. W. Brodrick, 1175, det. I. L. C.
Sphaerotheca Humuli (DC.) Burr. var. fuligina (Schl.) Salm., on Viola (cult. pansy), 1189; on Taraxacum officinale, Swan River, 491.
Uncinula Salicis (DC.) Wint., on Salix spp. and Populus spp. 148; Virden, 292; Grand Beach, 183; Victoria Beach, 1091.
Hypocreales: Claviceps purpurea (Fr.) Tul., on Agropyron tenerum, Bromus inermis, Calamagrostis canadensis, Elymus canadensis, E. innovatus, Panicularia grandis, Secale cereale, Triticum aestivum, 119, 118, 197, 269; I. L. C., 152, F. J. Higham, 124; Deloraine, 111; Clandeboye,

V. W. Jackson, 1197; Roblin (W. Rae); common and often destructive to wild grasses, common on rye.

Gibberella Saubinetii (D. and M.) Sacc. Fusarium stage on Triticum aestivum, W. H. Mackie Aug. 1920, 374. Quite common in 1921.

Hypomyces lactifluorum (Schw.) Tul. On Lactarius piperatus, L. spp., 333, 581, Gimli, 582, Minaki, 786. Very common.

Nectria cinnabarina (Tode) Fr. On Prunus spp., 395; Stony Mountain, 891; Swan River, 1032.

N. episphaeria (Tode) Fr., near Kenora, 914*S*.

N. Peziza (Tode) Fr., St Charles, 949*S*.

Dothidiales: Phyllachora graminis (Pers.) Fcl., on Elymus virginicus, E. canadensis, 72; Neepawa, I. L. C., 108.

Plowrightia morbosa (Schw.) Sacc., on Prunus spp., Virden, 287; Stony Mountain, 892; Swan River, 1033. Very common, and often destructive on wild plums, etc.

Sphaeriales: Anthostoma adustum (C. and P.) Sacc., on old wood, 1168*Br.*

Daldinia concentrica (Bolt.) Ces., on wood, 231, 327, 842, 438; Swan River, 1025.

Didymosphaeria manitobiensis Ell. and Ev., on Rubus (probably R. strigosus), coll. J. Dearness on banks of little Saskatchewan River, Oct. 3, 1891. Reference in N.A. Pyrenomycetes, p. 732. Specimen at Ottawa, from original collection.

Diatrype spp., 948*Br.*, 423*Br.*

Gnomonia ulmea (Schw.) Thuem. Conidial stage on Ulmus leaves, J. J. Christensen and G. R. B., 315*D*.

Gnomoniella Coryli (Batsch) Sacc., on Corylus americanus leaves, 179.

Hypoxylon commutatum Nits., on old wood, 947*Br.*

H. fuscum (Pers.) Fr., on old wood, 733*B.*, 954*S*.

H. Morsei B. and C., on wood, I. L. C. and G. R. B., 425*Br.*

H. rubigninosum (Pers.) Fr., 739*B.*

Lasiosphaeria strigosa (Alb. and Schw.) Sacc., on wood, 421*S*.

Physalospora Cydoniae Arnaud, Sphaeropsis stage on leaves of Pyrus malus, Morden, coll. A. V. Mitchener, 1050 det. H. T. Güssow. This fungus has not been found to be common on apple.

Valsa translucens de Not., on wood, 937*Br.*

Venturia inaequalis (Cke.) Aderh., on leaves of Pyrus malus, 216, 324, 187. Common but not ordinarily serious on apple.

FUNGI IMPERFECTI.

This list of imperfect fungi is obviously very incomplete. Most of the identifications are by the courtesy of Dr Davis. Few saprophytic forms have been collected.

Alternaria Solani (E. and M.) Jones and Grout, on potato leaves, Gilbert Plains, 1062; common over Manitoba in 1921 but not serious.

Asteroma Gentianae Fcl., on Dasystephana (Gentiana) Andrewsii, 1138*D*. Dr Davis reports that this fungus has been confused with Phyllosticta (Depazea, Leptothyrium) gentianaecola.

Botrytis Paeoniae Oud., on Paeony (cult.), 89. Sometimes injurious.

Cephalothecium roseum Cda., on citron fruit, 298; on Prunus fruit, Swan River, 1074; on Lentinus, 1098.

Cercospora althaeina Sacc., on cultivated hollyhock, 1132*D*.

C. avicularis Wint., on Polygonum aviculare, Lazare, 1128*D*.

C. dubia (Reiss) Wint. (C. Chenopodii Fres.), on Chenopodium album, Carberry, I. L. C., 1157*D*.

C. manitobana J. J. Davis, sp. nov. Spots brown, subcircular, 1–5 mm. in diameter above, less distinct below; conidiophores hypophyllous, fasciculate, fuligenous, straight or incurved or somewhat undulate, simple, sometimes septate, more or less nodulose, 35–60 × 3–4 μ; conidia hyaline, obclavate, straight, becoming 1-septate, 50–63 × 4–6 μ.

On leaves of Shepherdia argentea, Gilbert Plains, Manitoba, coll. July 27, 1921, G. R. Bisby, No. 1125. Type in J. J. Davis' collections, co-type at Man. Agr. College. The trichomes give a somewhat cinereous appearance to the spots.

C. rhoina C. and E., on Rhus Toxicodendron, Thunder Hill, 1136*D*.

Cladosporium subsessile Ell. and Barth., on Populus leaves, 316*D*. Common.

Colletotrichum salmonicolor O'Gara, on stems of Asclepias sp., 318*D*.

Cylindrosporium Padi Karst. (Coccomyces), on leaves of Prunus, 311; Eden, 459.

Cystospora chrysosperma (Pers.) Fr. (Valsa sordida Nke.?), on Populus, J. F. Higham, 446.

Darluca filum (Bib.) Cast., on sori of rusts. Common, especially on telia late in the season.

Discosia artocreas Fr. (?), on Rubus triflorus, 374*D*.

Fusarium conglutinans callistaphi Beach, on Aster (cult.) causing wilt. Common. The fungus was not fully determined as to species but is probably the above.

F. discolor sulphureum Schl., on potato tubers, causing rot. A number of isolations indicated that this is the commonest Fusarium in rotted potatoes in Manitoba.

F. Lini Bolley, on flax (cult.). Not common; definite record only from Winnipeg.

F. oxysporum Schl., on potato. Wilt of potatoes in Manitoba was found, so far as isolations were made, to be caused by this Fusarium.

Haplosporella diatrypoides E. and B.(?), 392*B*.

Helminthosporium gramineum (Rab.) Erik., on barley, 159, 167, Ste. Rose, 1010. Common and sometimes destructive.

H. sativum P. K. and B., on barley; Swan River, 495; everywhere in Manitoba causing considerable injury.

H. teres Sacc., on oats and barley, quite common but not found to be serious.

Phyllosticta livida E. and E., on Quercus macrocarpa, J. J. Christensen and G. R. B., 314*D*.

Ramularia Tulasnei Sacc. (apparently), on cult. strawberry, 123*D*.

R. Urticae Ces., on nettle, I. L. C. and G. R. B., 1191*D*.

Septoria conspicua E. and M., on Steironema ciliata, Ste. Rose, 1139*D*.

S. Convolvuli Desm., on Convolvulus sepium, Emerson, I. L. C., 1176*D*.

S. flagellifera E. and E., on Pisum sativum (cult.), 1150*D*.

S. lactucicola E. and M., on Lactuca sp. 317*D*. The same or a similar fungus also on Sonchus arvense.

S. musiva Pk., on Populus balsamifera, I. L. C., 1172*D*.

S. Oenotherae West, on Oenothera biennis, Gilbert Plains, 1126*D*.

S. ribis Desm., on Ribes (cult. gooseberry), 1194, 1195.

S. Sicyi Pk. (S. Brencklei Sacc.), on Micrampelis lobata, Morris, I. L. C., 313*D*.

S. Symphoricarpi E. and E., on Symphoricarpos sp., Morris, I. L. C., 319*D*.

Trichoderma lignorum (Tode) Harz, has been found.

Vermicularia (?; immature), on Smilax herbacea, 1130*D*.

Verticillium albo-atrum McA. Has been observed on rotting potato tubers.

BASIDIOMYCETES.

USTILAGINALES.

The writers have made no extended search for smuts in Manitoba, and this list includes principally conspicuous economic forms. The range of certain species is, however, extended. W. P. Fraser and I. L. Conners have helped in preparing this list.

Entyloma compositarum Farl., on Ambrosia trifida, Morris, I. L. C., 320*D*.

E. Menispermi Farl. and Trel., on Menispermum canadense, I. L. C., 194*D*.

Sorosporium Syntherismae (Peck) Farl., on Panicum milaceum, Keyes, 150*F*.

Sphacelotheca Sorghi (Link) Clinton, on Sorghum vulgare, 433.

Tilletia laevis Kuehn, on Triticum aestivum, listed by Clinton in N. A. Flora, VII, 48, 1906. This is the only smut from Manitoba listed in that work. The only bunt of wheat the writers have found is caused by T. Tritici; but T. laevis may also still occur in the Province.

T. Tritici (Bjerk.) Wint., on Triticum aestivum, 157. This smut is widespread over Manitoba, although not serious because of the common practice of treating seed wheat.

Urocystis Anemones (Pers.) Wint., on Pulsatilla patens, Brandon, W. P. F. and I. L. C., 380; also collected by Conners at Carberry.

U. occulta (Wallr.) Rab., on Secale cereale, V. W. Jackson, 299. Found by Prof. Jackson on volunteer rye beside the Biology Building, M. A. C.; also reported on the plots at the M. A. C., Winnipeg; not found in fields throughout the Province.

Ustilago Agropyri (?) on Agropyron tenerum, V. W. Jackson, 137. Common and more or less injurious to this grass.

U. anomala (J. Kunze) Wint., on anthers of Polygonum (Tiniaria) cilinode, A. H. R. B., Minaki.

U. Avenae (Pers.) Jens., on Avena sativa, 172, 310, Ste. Rose, 1011; Lonely Lake, 1072. Common and rather destructive to oats.

U. Hordei (Pers.) Kell. and Swingle, on Hordeum vulgare, Portage la Prairie, I. L. C., 107; Gilbert Plains, 1020. Common but does not cause much loss.

U. hypodytes (Schl.) Fries, on Stipa viridula, Rapid City, I. L. C., 173*F*.

U. levis (K. and S.) Magn., on Avena sativa, 309. Not very common.

U. Lorentziana Thuem., on Hordeum jubatum, Boissevain, I. L. C., 182*F*.

U. neglecta Niessl., on Chaetochloa glauca, 297.

U. striaeformis (West.) Niessl., on Beckmania erucaeformis, I. L. C. and H. Groh., 1088*J*. Prof. H. S. Jackson reports that this is the first time he has seen a smut on this host, but that the smut agrees with U. striaeformis though there may be strains.

U. Tritici (Pers.) Rostr., on Triticum aestivum, 176, 180, Oakville, V. W. Jackson, 302; Binscarth, 472; Gilbert Plains, 1066. Common, sometimes causing 10 % loss of wheat.

U. Zeae (Beckm.) Unger, on Zea Mays, Glenora, 358. Very prevalent in 1921.

U. sp. on Phragmites Phragmites. Delta, V. W. Jackson, 1089*J*. H. S. Jackson reports that this may possibly be U. mirabilis Sorokin, heretofore known only from Russia.

UREDINALES.

List compiled with the assistance of W. P. Fraser and I. L. Conners.

The number of rusts in Manitoba is necessarily somewhat limited because of the short growing season, the relatively small range of hosts, and the absence of marked variation throughout the province in elevation, precipitation, etc.

The 80 species here listed fall in 19 genera. Only some eight species (five Puccinia, two Polythelis, one Nyssopsora) are short cycled (telia only or pycnia and telia).

The North American Flora (vol. VII) has in general been followed, except that Puccinia and Uromyces names are used.

Aecidium Allenii Clinton, I on Eleagnus argentea, Russell 1002. Probably a stage of Puccinia Rhamni.

Calyptospora columnaris (Alb. and Schw.) Kuehn, III on Vaccinium sp., Minaki.

Coleosporium Solidaginis (Schw.) Thuem., II on Solidago spp. 149, Swan River Valley, 476, 481; Ste. Rose du Lac, 1058; Lonely Lake, 1073; Victoria Beach, 1086; on Aster spp. 146, 1083, Grand Beach, 146; on cultivated asters, 1187; on Doellingeria sp., Lonely Lake, 1056. The mycelium of this rust overwinters in the perennial parts of the plants; aecia have not been found here.

Cronartium Comandrae Peck, II, III on Comandra pallida, Victoria Beach; V. W. Jackson, 1090; common.

Earlea speciosa (Fries) Arth., on Rosa spp., Brandon and Oak Lake, W. P. F.; Eden, 461; Morris, I. L. C., 127; common.

Gymnoconia interstitialis (Schl.) Lagerh., I on Rubus triflorus, Ochre River, V. W. Jackson, 236; Eden, 452. This interesting rust (the longer cycle form) occurs commonly in northern regions. Germination of the aeciospores of the Eden collection showed that they produced germ tubes.

Gymnosporangium cornutum (Pers.) Arth., I on Sorbus americana, Minaki, 611.

G. germinale (Schw.) Kern., I on Crataegus sp., 218. Not uncommon.

G. juvenescens Kern., I on Amelanchier alnifolia, 75, 199, 247*J*.; Eden, 458. Collected also at Brandon and Rapid City, I. L. C.; III on Juniperus horizontalis, Millwood, 497. Frequently found on Amelanchier.

Melampsora Bigelowii Thuem., on Salix spp., Gilbert Plains, 1016; common throughout the Province; collected by V. W. Jackson along the Hudson Bay Railway, 241. "Overwinters in buds and twigs, the uredinia sometimes occurring on opening leaves in the spring." W. P. F.

M. Lini (Schm.) Desmaz., I, II, III on Linum usitatissimum, 229, 1129. II abundant on volunteer flax, collected as late as Oct. 8, 1920, 284. A rather serious disease of flax in Manitoba. II on Linum Lewisii, Russell, 1006; Baldur, I. L. C., 1147.

Melampsorella elatina (Alb. and Schw.) Arth., I on Abies balsamea, Brandon, I. L. C.; II on Cerastium arvense, Brandon, W. P. F.

Melampsoropsis Pyrolae (DC.) Arth., II, III on Pyrola rotundifolia, W. P. Fraser and V. W. Jackson, 251.

Nyssopsora clavellosa (Berk.) Arth., III on Aralia nudicaulis, 1081; Swan River, 1079.

Phragmidium americanum Diet., on Rosa sp. (cult.), 125; reported also from Brandon. This and the other Phragmidia on roses are referred with some doubt as to specific name.

P. imitans Arth., on Rubus strigosus, Brandon, I. L. C., (III) 226*J*.; (II) 227.

P. montivagum Arth., on Rosa blanda, Virden, 222, Morris, I. L. C. Wild roses as far north as Swan River are abundantly affected with rust. Several collections are only in the aecial stage, and it is not certain to which species they belong.

P. Potentillae (Pers.) P. Karst., I, II, III on Potentilla bipinnatifida, P. pennsylvanica, P. strigosa, P. glabrella, P. spp.; Virden, 130*J*.; Lake Clementi, I. L. C., 178, Reston, 437; Stony Mountain, 434; Millwood, 498; Swan River, 496. Common.

Pileolaria Toxicodendri (Berk. and Rav.) Arth., III on Rhus Toxicodendron, 77*J*.; Brandon, W. P. F.

Polythelis Pulsatillae (Rostr.) Arth., on Pulsatilla ludoviciana, Virden, coll. P. R. Cowan, det. W. P. F.

P. Thalictri (Chev.) Arth., III on Thalictrum venulosum, I. L. C., 1171*F*.

Puccinia abundans (Peck) Jackson, I on Symphoricarpos sp., 214, 79; Russell, 1004; Rapid City, I. L. C.

P. amphigena Dietel. Reported by W. P. F., I on Nemexia lasioneuron, Brandon; and II, III on Calamovilfa longifolia.

P. Andropogonis Schw. (P. pustulata Arth.), I on Comandra pallida, 81.

P. angustata Peck. Reported by W. P. F., I on Mentha canadensis, Brandon, Dauphin; and II, III on Scirpus microcarpus, Brandon. (See Mycol. XI, 130.)

P. Antirrhini Diet. and Holw., II on Antirrhinum majus (cult.), greenhouse, M. A. C. J. F. Higham, Mar. 1920 (first report for Manitoba). During 1920,

it became destructive in gardens around Winnipeg; 73, 131, 195. Probably occurred previous to 1920, but was not noted. Not found in 1921.

P. Asparagi DC., II, III on Asparagus officinalis, 270; Brandon, W. P. F. Not found to be serious.

P. Asperifolii (Pers.) Wettst., II on Secale cereale, I. L. C., 142; V. W. Jackson, 274; Swan River, 474. Common, but not serious on rye.

P. Asteris Duby, III on Aster Novae-Angliae, reported by W. P. F., Brandon.

P. Asterum (Schw.) Kern., I on Solidago rigida, S. spp., Aster spp., Grindelia squarrosa, 76, 295, 294, 211; Brandon, W. P. F.; Morris, I. L. C., 93; Virden, 291; Riding Mountains, 466; Swan River, 488; II, III on Carex scoparia, Brandon, W. P. F.

P. calthaecola Schr., I, II, III on Caltha palustris, Dauphin, W. P. F.

P. Cicutae Thuem., on Cicuta maculata, Brandon, W. P. F.

P. Cirsii Lasch, on Carduus Flodmani, Brandon, W. P. F.

P. Clematidis (DC.) Lagerh. (including P. Agropyri); I on Anemone canadensis, A. sp., 163; Morris, I. L. C., 196; Gilbert Plains, 1060; Lazare, 499; Swan River, 482; on Thalictrum dasycarpum, T. venulosum, 126, 71; Morris, I. L. C., 201, Eden, 454; Virden, 290; Swan River, 1076; on Actaea alba, A. rubra, 155*J*., 156, 293; Eden, 455. II, III on Bromus ciliatus, Neepawa, I. L. C., 105; Elymus virginicus, 267; E. Macounii, Morris, I. L. C., 210. Also collected by W. P. F. on Agropyron tenerum, A. Richardsonii, A. Smithii, Bromus latiglumis, Elymus canadensis, Hordeum jubatum, Poa arida. A very common rust in Manitoba. For cultures made by Prof. Fraser, see Mycol. XI, 133, 1919. Collections on Bromus are of the P. tomipara type.

P. Distichlidis Ellis and Ev., I on Steironema ciliata, Morris, I. L. C., 124; Brandon, W. P. F.; II, III on Spartina Michauxiana, Waskada, 100; Brandon, W. P. F.

P. Eatoniae Arth., I on Ranunculus abortivus, Riding Mountains near Kelwood, 464. Placed here with some uncertainty, but the distributed aecia suggest this rust.

P. Eleocharidis Arth., I on Eupatorium purpureum, Brandon, W. P. F.; II, III on Eleocharis sp., Brandon, W. P. F.

P. Ellisiana Thuem., I on Viola canadensis, V. sp., 122, 87; II, III on Andropogon furcatus, Brandon, W. P. F.

P. epiphylla (L.) Wettst., II on Poa pratensis, P. sp., V. W. Jackson, 249, 250.

P. graminis Pers. I on Berberis vulgaris, 202, 138, 252; Brandon, 282. II, III on Triticum aestivum, first found during 1920 on June 30th, at Winnipeg; during 1921, on June 27th, at Emerson; thenceforth northward and soon found everywhere. On Hordeum vulgare, 181, 206, 259; on Avena sativa, A. fatua, 145, 204, 258; V. W. Jackson, 273; on Phleum pratense, 161, 275; Swan River, 480; Gilbert Plains, 1067. The II stage evidently lives over winter on timothy, since the rust can be found on timothy before it appears on grains. On Agropyron repens, A. tenerum, A. caninum, A. Smithii, 153, 261, 213, 208, 260, 262; Lyleton, 97; on Hordeum jubatum, 192, 193, 154, 117; Lyleton, 96. On Elymus Macounii, E. canadensis, 160, 278, Morris, I. L. C., 70. On Dactylis glomerata, 263; on Alopecurus pratensis; The Pas, V. W. Jackson, 266; on Festuca elatior, 265. On Beckmannia erucaeformis, Roblin, W. Rae. Also on other hosts. This is by far the worst plant disease in Manitoba.

P. Grossulariae (Schum.) Lagerh. I on Grossularia spp. and Ribes americanum, R. spp., wild and cultivated, 132, 441, Matlock, 133; Morris, I. L. C., 200; Eden, 457; Virden, 286. II and III on Carex spp., Brandon, W. P. F.

P. Helianthi-mollis (Schw.) Jackson, I, II, III on Helianthus annuus (cult.), H. fascicularis, H. sp., 470, 92, 171, 165; Portage la Prairie, I. L. C., 101; Brandon, I. L. C., 177; Melita, 110; Waskada, 98; Russell, 1007; Dauphin, W. P. F.

P. hemisphaerica (Peck) Ell. and Ev., I, II, III on Lactuca pulchella, 86, 255, 256, 1082; Lazare, 1001; Gilbert Plains, 1064; Thunder Hill, Swan River, 483.

P. hieraciata (Schw.) Jackson (P. patruelis Arth.), I on Lactuca pulchella, Nabalus albus, 86; Morris, I. L. C., 95; Eden, 462; Brandon, W. P. F.; II, III on Carex spp., Brandon, W. P. F.

P. Impatientis (Schw.) Arth., 0, I on Impatiens biflora, 191; Swan River, 492, 1080; Dauphin, W. P. F. Cultured by Prof. Fraser to Hordeum jubatum (Mycol. XI, 131, 1919).

P. Lygodesmiae, Ell. and Ev., on Lygodesmia juncea, Brandon and Virden, W. P. F.

P. Magnusianum Koern., II, III on Phragmites Phragmites, Dauphin, W. P. F.

P. Majanthae (Schum.) Arth. and Holw., I on Vagnera stellata, Unifolium canadense, 80, 83, Brandon, W. P. F.; II, III on Phalaris arundinacea, Brandon, W. P. F.

P. marylandica Lindr., I on Sanicula marylandica, 306; Brandon, W. P. F.

P. Menthae Pers., II on Mentha glabrior, M. canadensis (?), Monarda fistulosa, M. mollis, Gilbert Plains, 1059; Swan River, 486; Brandon, Dauphin, W. P. F.; Waskada, 99; Grand Beach, 162.

P. monoica (Peck) Arth., I on Arabis sp., W. P. F.; II, III on Trisetum spicatum, The Pas, V. W Jackson, 257.

P. montanensis Ellis, II, III on Agropyron Smithii, Elymus canadensis. Brandon, Dauphin, W. P. F.

P. Peckii (De Toni) Kellerm., I on Oenothera biennis, 88, 240; II, III on Carex Sartwelli, Brandon, W. P. F.

P. Polygoni-amphibii Pers., II, III on Polygonum Hartwrightii, P. Muhlenbergii, 143; Gilbert Plains, 1015, 1065; Swan River, 490.

P. Rhamni (Pers.) Wettst. (P. coronata Corda), I on Rhamnus alnifolia, R. cathartica, 136, 203; Morris, I. L. C., 78; Swan River, 484; Brandon, W. P. F.; II, III on Avena sativa. Calamagrostis canadensis, C. Langsdorfii, Beckmannia erucaeformis, Sclerochloa festucacea, Bromus sp., 204, 283; I. L. C., 106, 129; Swan River, 484; Brandon, W. P. F.; The Pas, V. W. Jackson, 281; Grand Beach, 209.

P. rubefaciens Johans., on Galium boreale, Brandon, W. P. F.

P. rubella (Pers.) Arth., I on Rumex mexicanus, R. occidentalis, Dauphin, W. P. F.; II, III on Phragmites Phragmites, Dauphin, W. P. F. (See Mycol. XI, 130, 1919.)

P. Sherardiana Koern., on Malvastrum coccineum (not certain).

P. Sorghi Schw., II, III on Zea Mays, 467, 469. These are the first specimens known to be collected in Manitoba. The rust came to be very abundant in 1921.

P. Stipae Arth., II, III on Stipa comata, W. P. F.

P. substerilis Ellis and Ev., III on Stipa viridula, Rapid City, I. L. C., 113*F*.; Brandon, W. P. F.; common.

P. Taraxaci (Reb.) Plowr., III on Taraxacum officinale, 121, 190, 1085; Gilbert Plains, 1063.

P. triticina Eriks., II, III on Triticum aestivum, 207; Ste. Rose, 1014, 1069; Swan River, 473. Occurred wherever wheat was grown in Manitoba in 1921, and caused considerable loss.

P. universalis Arth., 0, I on Artemisia gnaphaloides, Brandon, W. P. F.; II, III on Carex praegracilis, Brandon, W. P. F.

P. Urticae (Schum.) Lagerh., I on Urtica Lyalli, U. gracilis(?), Morris, I. L. C., 94; Swan River, 1075; Dauphin, W. P. F.; II, III on Carex spp., Brandon, W. P. F.

P. Xanthii Schw., III on Ambrosia trifida, Morris, I. L. C., 104.

P. Ziziae Ell. and Ev., on Zizia aurea, Brandon, I. L. C., 1198.

Pucciniastrum arcticum (Lag.) Tranz., II, III on Rubus triflorus, W. P. F.; V. W. Jackson, G. R. B., 223*J*.

P. pustulatum (Pers.) Diet., II, III on Epilobium adenocaulon, Brandon, W. P. F.

P. Pyrolae (Pers.) Diet., on Pyrola rotundifolia, 364*D*, 84.

Uredinopsis Struthiopteridis Storm., II, III on Onoclea Struthiopteris, 74; I. L. C and G. R. B., 158*J*.; 468. Common.

Uromyces acuminatus Arth., 0, I on Smilacina stellata and II, III on Spartina michauxiana, Brandon, W. P. F.

U. Alopecuri Seym., I on Ranunculus Macounii, R. scleratus, Brandon,

W. P. F., and collected on and cultured to Alopecurus aristulatus (Mycol. XI, 129, 1919). Aecia considered to belong to this rust were collected in the Riding Mountains near Kelwood, 463.

U. Fabae (Pers.) de Bary, I, II, III on Lathyrus ochroleucus; Viola americana, 221; Swan River, 489, 478, 1078; Neepawa, I. L. C., 215; Gilbert Plains, 1019; Brandon, I. L. C., 184.

U. Glycyrrhizae (Rab.) P. Magn., on Glycyrrhiza lepidota, V. W. Jackson, 1137; Swan River, 1077; Morris, I. L. C., 217.

U. Junci (Desm.) Tul., II, III on Juncus balticus, Brandon and Oak Lake, W. P. F.

U. Polygoni (Pers.) Fcl., I, II on Polygonum aviculare, 85, 248.

U. porosus (Peck) Jackson, on Vicia americana, I. L. C., 1095.

U. proeminens (DC.) Pass., II, III on Euphorbia (Chamaesyce) sp., 242.

U. Trifolii (Hedw. f.) Lév., I, II, III on Trifolium repens; T. hybridum, 169, 168, 166, 245; Swan River, 479. Aecia are common and were collected as late as Aug. 24th, 1921, 1096.

Tremellales.

Exidia albida (Huds.) Bref. (?), Kenora.
E. glandulosa (Bull.) Fr., 362, 602; E. C. Stakman and A. H. R. B., 805; Kenora, 570.
Tremella clavarioides, 1162*Ll.*
T. mycetophylla Peck, on Collybia dryophila, coll. A. H. R. B.
Ulocolla foliacea (Pers.) Bref., on Abies balsamea, A. H. R. B.

Dacryomycetales.

Dacryomyces aurantia Schw., Kenora, 557*Ll.*
D. stillatus Fr. (?), 328.
Guepinia spathularia (Schw.) Fr., Kenora, 965.

Agaricales.

Thelephoraceae (including Hypochnaceae):
Aleurodiscus amorphus (Pers.) Rabenh., 20*V.*
A. cerussatus (Bres.) v. H. and L., 26*B.*, 65*B.* First record for North America.
Coniophora cerebella Pers., Kenora, 946*B.*
C. puteana Fr., Manitou, J. A. MacGregor, 1054*Ll.*
C. suffocata (Pck.) Massee, 925*B.*
Corticium arachnoideum Berk., 743*B*, Stony Mountain, 900*B.*
C. galactinum (Fr.) Burt, 1102*B.*
C. polygonium Fr., 394*B.*
C. roseum Pers., 936*B.*, Stony Mountain, 897*B.*
C. salicinum Fr., Shoal Lake, I. L. C., 429*B.*
C. vagum B. and C. Extremely abundant in the Rhizoctonia stage on potatoes throughout the agricultural areas of Manitoba, causing much damage. Also on other hosts, as sweet pea (Dauphin, 91).
C. vellereum E. and C., 720*B.*
Cyphella Tiliae (Peck) Cooke, 730*B.*
Eichleriella spinulosa (B. and C.) Burt, Swan River, 1048*B.*
Hymenochaete cinnamonea (Pers.) Bres., 31*V.*, 66, 731, 732*B.*, 944*B.*
H. Curtisii (Berk.) Marg., 736*B.*
H. rubiginosa (Dicks.) Lév., 748*B.* (resupinate).
H. tabacina (Sow.) Lév., 567*B.*
Hypochnus chalybaeus (Pers.) Bres., 1163*B.*
H. coriarius (Peck) Burt, coll. I. L. C. and G. R. B., 1215*W.*
H. fumosus Fr. (Corticium sulphureum Pers.), 1217*W.*
H. granulosus (Peck) Burt, 708*B.*
H. spongiosus Schw.?, 1158*B.*
Peniophora cinerea Bull., 10*V.*, 11*V.*, 25*V.*, 821, 878*B.*
P. crassa Burt (prob.), 26*xV.*

P. gigantea (Fr.) Burt, 28*V.*, 49*V.*
P. laevis (Fr.) Burt, 744*B.*
Stereum cinerascens Schw., 63*B.*, 740*B.*, 371, 945*B.*, 1118*B.*
S. fasciatum Schw., 746*B.*, 825*B.*
S. frustulosum (Pers.) Fr., 955*B.*, 956*B.*
S. fuscum (Schrad.) Quél. (S. bicolor Pers.), 741*B.*, 601*B.*, 1234*W.*, 827*B.*; Victoria Beach, 909*B.*; Shoal Lake, I. L. C., 427*B.*
S. gausapatum Fr., 34*V.*, 1235*W.*, 880*B.*, 1105*B.*, 721*B.*
S. purpureum Pers., 1231*W.*, 933*B.*, 938*B.*, 508*B.*, 722*B.*, 728*B.*, 826*B.*
S. rugum Fr., 24*V.*, 367, 500; Ethelbert, R. Pidruchney, 398; Swan River, 1028. Very common on fallen poplar branches.
S. versiforme B. and C. (Peniophora Ellisii Mass.), 1216*W.*
Thelephora laciniata Pers. (?), Minaki.
Clavariaceae: Calocera viscosa (Pers.) Fr., Kenora.
Clavaria abietina Fr., or C. flaccida Fr., 1160*Ll.*
C. cinerea Bull., 1159*Ll.*
C. formosa Fr., Victoria Beach.
C. pistillaris Fr., Kenora, 587, 797.
C. pyxidata Fr., Gimli, R. Hiebert, 628; Swan River, 1044; Russell; Gimli.
C. sp. (not in Cotton and Wakefield's paper), 1161*Ll.*
Typhula gyrans Fr., 1200*W.*
Hydnaceae: Grandinia spp., 44*V.*, 372*V.*, 879*B.*, 1182*B.*
Hydnum caryophylleum B. and C., 725*B.*
H. coralloides Scop., Gimli; Kenora, 538, 793.
H. ferrugineum Fr. (?), Minaki, 536.
H. imbricatum Fr., Minaki, 577.
H. Kauffmani Peck, 526*Ll.*
H. ochraceum Fr., 959*V.*
H. repandum Fr., Kenora, 563.
H. reticulatum (Banker) Sacc. and Trott (?).
Irpex ambiguus Peck (?), Winnipeg.
Mucronella minutissima Peck, coll. A. H. R. B.
Odontia fimbriata Pers., 726*B.*
O. fusco-atra Fr., Swan River, 1043*Ll.*
Phlebia cinnabarina Schw., 1177*B*
P. strigoso-zonata Schw., 58*V.*, 749*B.*, 877, 852, 1222*W.*; Minaki, 546.
Radulum spp., 1*V.*, 723*V.*
Tremellodon gelatinosum (Scop.) Fr., Kenora.
POLYPORACEAE: It will be observed that Dr Overholts has determined most of the species (those marked *V.*). The vicinity of Winnipeg has been fairly well surveyed for Polypores. The nomenclature used by Overholts has been followed and Polystictus is included under Polyporus.
Daedalea confragosa (Bolt.) Fr., 53*V.*, 784, 838*V.*; Kenora, 548.
D. unicolor Bull., 2*V.*, 598, 833, 839.
Favolus canadensis Klotz., 336, 555, 442, 1109; Kenora, 796; Swan River, 1031.
Fomes applanatus (Pers.) Wallr., 419; Shoal Lake, H. F. Roberts, 755*W.*; Russell, 1021*V.* and 1023*V.*
F. connatus Weinm. (F. populinus Fr. ?), 61*V.*, 752*V.*
F. fomentarius (L.) Gill., 841, 418, 951*V.*; Kenora, 700, 701*V.*; Shoal Lake, H. F. Roberts, 759. Common.
F. fulvus Scop. (?), 40*V.*
F. igniarius Fr. Common on living poplar, willow, ash, and other trees. Often reaches an age of 20 or 30 years or more. Quite destructive to trees. Tests showed that spore-fall in Manitoba occurs during July and August. Often resupinate, 15*V.*, 365, 953*V.*, 1114, 853; Kenora, 568, 703 and 705; Shoal Lake, H. F. Roberts, 758; Swan River, 1027.
F. pinicola Sw., 33*V.*, 845*V.*, 950*V.*; Gimli, R. Hiebert, 864; Swan River, 1039*V.*; Dr Overholts considers No. 845 to be a variation from the usual type.

F. (Trametes) scutellatus Schw., Kenora, 709*V*.
Lenzites abietina (Bull.) Fr. (? not certain that this species occurs in N. A., possibly L. saepiaria), 1045*V*., 588.
L. betulina Fr., 603, 846; Kenora, 548*V*.; Minaki, 573; Gimli.
L. saepiaria Fr. (Trametes protracta Fr. when poroid), 41*V*., 354, 750, C. W. Lowe, 586; Minaki, 572; Gimli.
L. trabeus (Pers.) Fr. (L. vialis Pk.), 50*V*.
Merulius ambiguus Berk., Shoal Lake, I. L. C., 428*B*.
M. corium Fr., 943*B*.
M. niveus Fr. (?), Kenora, 558*B*.
M. tremellosus (Schrad.) Fr., Kenora, 706*V*., 542*B*., Shoal Lake, H. F. Roberts, 829*B*.
Polyporus abietinus Fr., Swan River, 1046*V*.
P. adustus (Willd.) Fr., 5*V*., 16*V*., 17*V*., 517, 834, 38*V*. Very common.
P. albiceps Pk.?, 1100*V*.
P. betulinus Bull., 3*V*.; Kenora, 702; Shoal Lake, H. F. Roberts, 757*W*., Shoal Lake, I. L. C. (May 24, 1921; previous year's pileus producing spores), 1143*W*.
P. biformis Kl., 927*V*.
P. brumalis (Pers.) Fr., 45*V*., Kenora, 449, 704; Minaki, 545.
P. chioneus Fr., 876, det. E. C. Stakman.
P. cinnabarinus (Jacq.) Fr., Victoria Beach, 810. Not common.
P. conchifer (Schw.) Fr., 844*B*.
P. cuticularis Bull., 957*V*., Victoria Beach, 908*V*.
P. dichrous Fr., 13*V*., 27*V*., 856, 719*V*., 1178*V*.; Stony Mountain, 893.
P. elegans (Bull.) Fr., 37*V*., 824*W*., 1110; Gilbert Plains, 1051; Swan River, 1034.
P. fumosus (Pers.) Fr. (P. fragrans Pk.), 59*V*.
P. hirsutus Fr., 68*V*., 785, 875, det. E. C. Stakman, 907*V*.
P. lucidus Fr. (?), Kenora, 801.
P. pergamenus Fr. (including P. subchartaceus Murr.), 7*V*., 9*V*., 597, 754*V*.; Shoal Lake, H. F. Roberts, 760; Hillside Beach, 416; Ethelbert, W. N. Pidruchney, 399*V*., Stony Mountain, 896*V*.; Swan River, 1030. Common.
P. peckianus Cooke (?), 961*V*.
P. perennis (L.) Fr., 823*W*., 960*V*.; Kenora, 566*aV*., 905*V*.
P. picipes Fr., 906*V*; Gimli, 904*V*.
P. planellus Murr., 27*xV*., 1123*V*., 1121*V*. Quite common in Sept. 1921 at Winnipeg.
P. pubescens Schum. (?), Russell, 1022*V*.
P. spumeus (Sow.) Hornem. (P. occidentalis Murr.?), 935*V*.
P. squamosus Pers., small form, 14*V*.
P. sulphureus (Bull.) Fr., 836. Not common.
P. tulipiferus (Schw.) Overh., 4*V*., 36*V*., 23*V*., 30*V*., 32*V*., 818, 742, 952*V*., 1180*V*.; Kenora, 569*V*.; Swan River, 1037*V*. Common and rather variable in appearance.
P. tuberaster Fr. Sclerotia of what is perhaps this fungus (probably the same as Grifola tuckahoe Güssow) are common in fields. See Lloyd, Myc. Note 833.
P. ursinus Lloyd, 753*V*. Not common.
P. velutinus Fr., 6*V*., 8*V*., 19*V*., 751, 501*V*.; Stony Mountain, 894 and 928.
P. versicolor (L.) Fr., 35*V*., 54*V*., 831, 832, 840; Stony Mountain, 895*V*.
P. volvatus Peck. On spruce, Ethelbert, W. N. Pidruchney, 400*V*.; Swan River, 1026; Russell. Common northward in Manitoba.
Poria attenuata Peck, 43*V*., 48*V*.
P. calcea Fr., Swan River, 1036*B*.
P. eupora Karst., 1212*W*.
P. ferruginosa Schrad., 51*V*., 60*V*.
P. laminata Murr., 12*V*.
P. mutans tenuis Peck (?), 727*V*.
P. ornata Peck, or a similar species, 57*V*.

P. prunicola Murr., 46*V*.
P. Vaillantii Fr., 52*V*.
P. washingtonensis Murr. On deciduous wood, 21*V*.
Solenia anomala Pers., 554*B*.
S. fasciculata Pers. (det. G. F. Atkinson), Winnipeg, A. H. R. B.
Trametes carnea Nees, 39*V*., 352, 855, 396*V*., 747*V*.; Gilbert Plains, 1053; Swan River, 1040*V*.; Kenora, 552; Minaki, 543.
T. hispida (Bagl.) Fr., 745*V*., 902*V*., 448; Matlock, 348*V*.; Gimli, 903*V*.; Stony Mountain, 890; Gilbert Plains, 1052; Swan River, 1029. Common and variable.
T. rubescens Fr. (Poroid form of Daedalia confragosa (L. O. Overholts, 1120*V*.).)

BOLETACEAE: Boletinus pictus Peck, Kenora, 802.
Boletus flavus Wither., Kenora, Winnipeg.
B. scaber Fr., 717, 1119; seen at Swan River, Russell, Kenora. Common, and the only Boletus found in 1921.

AGARICACEAE: Although over a hundred gill fungi are here listed, very many more occur in Manitoba. Several of these are listed with question-marks, for it is difficult to get determinations of Agarics verified because they decay so rapidly. Dr Kauffman has determined a few. The nomenclature used by Kauffman is followed. The species are arranged by spore colour

Leucosporae: Amanita muscaria Fr., 323, 1122; Kenora, 710; Greenway, C. Vickers Jr., 1196. This poisonous mushroom was common in 1921 in August and September.
A. phalloides Fr., Kenora; no definite record known from Manitoba, but it probably occasionally occurs.
Amanitopsis vaginata Fr., Winnipeg, Victoria Beach, Kenora; common in July and August.
Armillaria mellea Fr., Winnipeg, Kenora.
Cantharellus aurantiacus Fr., Kenora, 556, 561.
C. cibarius Fr., Kenora.
C. umbonatus Fr., Minaki.
Clitocybe gigantea Fr., Gimli.
C. laccata Quél. (Laccaria Berkeley).
C. maxima Fr., Gimli, Minaki.
C. Trogii Sacc. (?), Kenora.
Collybia cirrhata Fr., Gimli, 814; Kenora, 848.
C. confluens Fr., F. J. Higham, 435.
C. dryophila Fr., 332, 447, 1124; Hillside Beach, 415.
C. racemosa Pers. (?), Minaki, 635.
C. tuberosa Fr., Kenora, 816, 847, 849; Gimli.
C. velutipes Fr., Apr. 3rd, 1921, 321; Gimli; Kenora.
Hygrophorus chrysodon Fr., Kenora, 857 and 560.
H. conicus Fr., Gimli.
H. niveus Fr., Gimli.
Lactarius deliciosus Fr. In a squirrel's nest, Treesbank, S. Criddle, 940*K*., Gimli, Minaki. For other fungi collected by squirrels see also Buller, A. H. R., Trans. Brit. Myc. Soc. VI, 355, 1920.
L. glyciosmus Fr., Minaki.
L. piperatus Fr., Winnipeg, Gimli, commonly parasitized by Hypomyces.
L. rufus Fr., Minaki.
L. torminosus Fr., Gimli. Reported by some to be poisonous.
L. uvidus Fr. ("very probably" *K*.). Another fungus collected by squirrels, Treesbank, S. Criddle, 939*K*. Considered poisonous to man and guinea-pigs, but not to rabbits (Kauffman). Dr Kauffman reports certain other fungi sent him from squirrels' nests to be probably Lactarii.
Lentinus lepideus Fr., Ste. Rose, 1009; Deloraine; Selkirk. Everywhere on railway ties; also collected on living Negundo aceroides, I. L. C., 1055*K*.
Lenzites, see Polypores.
Lepiota naucina Fr., 1211.

Marasmius epiphyllus, Fr., 1181*K*.
M. oreades Fr., 843.
M. rotula Fr., 1144*K*.
M. siccus Schw.(?), Winnipeg.
M. urens Fr., det. E. C. Stakman. Reported by some to be poisonous.
Mycena alcalina Fr., Minaki, Kenora.
M. galericulata Fr., 1115; Kenora.
M. pura Fr., Kenora.
Omphalia campanella Fr., Kenora, 562, 716, 860.
O. campanella badipus, Kenora, 799.
O. epichysium Fr.(?), I. L. C., Winnipeg.
Panus rudis Fr., 854; Victoria Beach, 809.
P. stypticus Fr., 502.
Pleurotus circinatus Fr., Winnipeg.
P. ostreatus Fr., 335, 600; Swan River.
P. ulmarius Fr., 347, 585. Common on elms and maples around Winnipeg.
Russula aeruginea Lindbl., I. L. C., 1203.
R. aurantialutea Kauff., from a squirrel's abode, Minaki, Dr C. N. Bell, 931*K*.
R. emetica Fr., 1204; Swan River; Minaki.
R. integra Fr., Minaki, Gimli.
R. nitida Fr (?), Gimli.
R. virescens Fr., Kenora.
Schizophyllum commune Fr., 506, 589, 777, 112, 355; E. C. Stakman and A. H. R. B., 804; Swan River, 1024. Very common everywhere.
Trogia crispa Fr., 619; Kenora, 712.
Rhodosporae: Claudopus nidulans Fr., 851; Gimli, 584.
Pluteus cervinus Fr., Winnipeg; Gimli; Kenora, 713.
Volvaria speciosa Fr., Mr Rigby, 337; Gimli.
Ochrosporae: Cortinarius armillatus Fr., Minaki, 571.
C. cinnamomeus Fr.(?), Kenora.
C. mucifluus Fr., Minaki, 541; Kenora, 714.
C. violaceus Fr.(?), Kenora.
Crepidotus herbarum Pk., Swan River, 1104*K*.
C. mollis, Fr., 443.
C. versutus Pk., Gimli.
Flammula sapinea Fr., Gimli.
Galera hypnorum Fr., Pointe du Bois.
G. tenera Fr., Gimli, 642.
Hebeloma sp., Russell.
Inocybe sp., Winnipeg.
Naucoria hamadryas Sacc., Hillside Beach, 414.
N. pediades Fr., 331.
N. semiorbicularis Fr., Winnipeg.
Paxillus involutus Fr.(?), Winnipeg.
P. panuoides Fr., on sawdust, Gimli.
Pholiota adiposa Fr.
P. dura Bolt. (?), St Charles.
P. erinaceella Pk., I. L. C., J. F. Higham, G. R. B., 1103*K*.
P. squarrosa Quél.(?), Gimli, 583. This species may be limited to Europe, according to Kauffman.
P. squarrosoides Pl.(?), Minaki, 576.
Porphrosporae: Hypholoma appendiculatum Fr., Winnipeg, Stony Mountain.
H. fasciculare Fr., Gimli.
H. incertum Pk. var. sylvestris Kauff., 1106.
H. perplexum Pk., Winnipeg.
Psalliota (Agaricus) campestris Fr., bisporous form, C. W. Lowe, 763.
P. campestris Fr., quadisporous form, Gimli.
P. sylvatica Quél. (?), Kenora, 549.
Stropharia epimyces (Pk.) Atk., 882. Det. E. C. Stakman; reported by Kauffman to have been seen by Pennington at Winnipeg.

S. semiglobata Fr., Gimli.
Melanosporae: Anellaria separata Karst., Gimli.
Coprinus atramentarius Fr., 634, 789, C. W. Lowe, 790, 1108.
C. comatus Fr., C. W. Lowe, 787, 792.
C. curtus Kalchbr. Common at Winnipeg.
C. domesticus Fr., Winnipeg.
C. ephemerus Fr., Winnipeg.
C. Hendersonii Berk. On horse-dung, Winnipeg.
C. lagopus Fr. (C. fimetarius Fr.), Winnipeg.
C. micaceus Fr., 330; common.
C. narcoticus Fr., Winnipeg.
C. niveus Fr., Winnipeg.
C. plicatilis Fr., 835.
C. stercorarius Fr., 815, 817, 887, 888.
C. sterquilinus Fr., R. Hiebert, 627.
Gomphidius glutinosus Fr., Kenora, 798.
G. viscidus Fr., Kenora 550; Minaki, 575.
Panaeolus campanulatus Fr., 440, 436; Hillside Beach, 413; Thunder Hill.
P. papilionaceus Fr., 1201.
P. solidipes Peck, Winnipeg, A. H. R. B.; Sturgeon Creek, C. W. Lowe, 791.
Psathyra persimplex Britz., 1209.
Psathyrella disseminata Fr., 424, 1107.
P. crenata (Lasch.) Fr.(?), 1205.

PHALLALES.

Dictyophora Ravenelii (B. and C.) Burt, Kenora, 613.

LYCOPERDALES.

Bovista plumbea Pers., 378*Ll.*; Gimli, 529*Ll.*; Kenora, 884.
Calvatia coelata (Bull.) Morg. (?), Gimli, 533.
C. gigantea (Batsch) Morg., 339; Gimli.
C. pachyderma (Peck) Morg. (?), Gimli, 535.
Geaster coronatus Schaeff., Kenora, 813*Ll.* Very similar to L. minimus.
H. hygrometricus Pers., Victoria Beach, 812*Ll.*
G. rufescens Schm., 599*Ll.*
Lycoperdon cepaeforme Bull., 811*Ll.*, Gimli, 531*Ll.*
L. gemmatum Batsch, 837*Ll.*
L. piriforme Schaeff., 921*Ll.*, 370*Ll.*; Matlock, 383; Eden, 450; Shoal Lake, H. F. Roberts, 828*Ll.*
L. polytrichum Lloyd, Point du Bois, 918*Ll.*
L. Wrightii Berk., Gimli, 530*Ll.*
Mycenastrum corium Desvaux, 379*Ll.*
Secotium acuminatum Mont., Gimli, 624; Sturgeon Creek, 625.
Sphaerobolus stellatus Tod., Kenora.
Nidulariales: Crucibulum vulgare Tul., Kenora, 929.
Cyathus striatus (Huds.) Hoffm., 596, 349; Kenora.
C. vernicosus (Bull.) DC., 338.
Nidularia pisiformis (Roth.) Finl., Kenora, 964.
Uncertain: Ptychogaster subiculoides, named by Lloyd from 1164 sent him. Quite common in 1921, but never developed into anything definite.

LICHENS.

The majority of the species listed for convenience here were collected by John Macoun, principally from Lake Winnipegosis and other points north of the agricultural area of Manitoba, and listed in his paper "Catalogue of Canadian Plants. Part VII. Lichens and Hepaticae." Geol. Survey of Can. 1902, pp. 49–180. Macoun lists 614 lichens for Canada, and Fink (Minn. Bot.

Stud. III, 167–236, 1903) records 310 from the northern boundary of Minnesota (most of which naturally occur also in Manitoba); it is obvious that this list covers but a small fraction of the forms which occur in Manitoba.

The letter "*M.*" after a record indicates that the species is listed by Macoun. Where the names he used differ from those used by Smith (A Monograph of the British Lichens, 1918 and 1911), the name in Macoun's list is included in parenthesis.

Alectoria jubata (L.) Ach. (Bryopogon jubata var. implexa, Fr.), Porcupine Mts., *M.*

Arthonia patellulata Nyl., on aspen poplar trees, Moose Mt., July 3rd, 1880, *M.*

A. radiata var. Swartziana (Ach.) Sydow (A. Swartziana Ach.), on balsam fir, Lake Winnipegosis, *M.*

Biatorella moriformis (Ach.) Th. Fr. (Biatora moriformis Ach.), on bark and dead wood, Lakes Manitoba and Winnipegosis, July 2nd, 1881, *M.* Reported in Macoun's list only from Manitoba.

Bilimbia sabuletorum B. and R. (Biatora hypnophila (Turn.) Tuckerm.), on moss along Lake Winnipegosis, *M.*

B. sphaeroides (Dicks.) Koerb. (Biatora sphaeroides (Dicks.) Tuckerm.), on moss at base of trees, Red Deer River, Porcupine Mts., *M.*

Cladonia alpestris (L.) Rabenh. (C. sylvatica var. alpestris L.), on Duck Mts., *M.* Fox Lake, Ont., 606.

C. coccifera (L.) Willd., coll. A. H. R. B.

C. crispata Flot. (C. furcata (Huds.) Fr. var. crispata Floerk.), on earth, Red Deer River, Porcupine Mts., *M.*

C. crystatella Tuck., 632; Fox Lake Ont., 605.

C. deformis (L.) Hoffm., on earth, Red Deer River, Porcupine Mts., *M.*

C. fimbriata var. simplex Wainio (var. tubaeformis Fr.), on rotten logs, Lake Winnipegosis, *M.*

C. fimbriata var. radiata Cromb., on the Porcupine Mts., *M.*

C. gracilis (L.) Willd. var. hybrida Schaer., at Lake Winnipegosis, *M.*

C. gracilis var. elongata Fr., on old logs, Red Deer River and Porcupine Mts., *M.* (Perhaps same as preceding.)

C. pyxidata (L.) Hoffm., Red Deer River and Lake Winnipegosis, *M.*, 633.

C. rangiferina (L.) Web., 762. The Reindeer Moss.

C. squamosa Hoffm., Lake Winnipeg (Herb. Hooker), *M.*

C. sylvatica (L.) Hoffm., in woods, Duck Mts., *M.*

C. turgida Hoffm. var. conspicua (Schaer.) Nyl., in woods, Duck Mts., *M.*

Collema tenax (Sw.) Sm., on earth, Otterbourne, *M.*

Evernia prunastri (L.) Ach., on trees, Duck Mts. and Lake Winnipegosis, *M.*

Graphis scripta Ach. var. limitata Schaer., on bark along Lake Winnipegosis, *M.*

Gyalecta lutea (Dicks.) Tuckerm., on spruce bark along Red Deer River, Porcupine Mts., *M.*

Gyrophora polyrrhiza (L.) Krb., Minaki, 626.

Lecanactis premnea Ach. var. chloroconia Tuckerm., on white spruce bark, Swan Lake House, Lake Winnipegosis, *M.*

Lecanora subfusca (L.) Ach. var. allophana Ach., on aspen poplar, Greenwood Twp. (Thos. Walker); on trees along Lake Winnipegosis, *M.*

Lecidea enteroleuca Fr. var. achrista Sommerf., on bark of trees along Lake Winnipegosis and on Moose Mts., *M.*

L. parasema Ach. (Buellia parasema Th. Fr.), on bark of paper birch, Red Deer River, Porcupine Mts., *M.*

L. vernalis (L.) Ach. (Biatora vernalis Fr.), on bark of trees, Red Deer River, Porcupine Mts., *M.*

Nephromium resupinatum D. T. and S. ("Nephroma tomentosum (Hoffm.) Koerb."), on trees, Manitoba House, *M.*

Parmelia caperata (L.) Ach., on dead wood, Manitoba House, *M*.
P. saxatilis (L.) Ach., on trees, Red Deer River; collected also by A. H. R. B.
P. sulcata Tayl., on rocks, Fox Lake, Ont., Dr F. C. Bell, 525.
P. tiliacea (Hoffm.) Ach., on rocks, Kenora, 807.
Peltigera aphthosa (L.) Willd., on earth in woods, Duck Mts., *M*.
P. canina (L.) Willd., coll. A. H. R. B.
P. rufescens (Neck.) Hoffm., on earth, Manitoba House, *M*.
Physcia hispida (Schreb.) Tuckerm., on poplar trees, Stony Mt., *M*.
P. orbicularis D. T. and S. (P. obscura (Ehrb.) Nyl.), on trees, Lake Winnipegosis, *M*.
P. stellaris (L.) Nyl., on trees at Winnipeg and Manitoba House, *M*.; C. W. Lowe, 770; common.
Placodium cerinum (Hedw.) Hepp., along Red Deer River, *M*.
Stereocaulon paschale (L.) Fr., on rocks, Kenora, Miss M. G. Rioch, 769; Fox Lake, Ont., 607.
Theloschistes chrysophthalmus (L.) Th. Fr., on trees, Lake Winnipegosis, *M*.
Usnea barbata Web. (U. barbata var. dasypoga Fr.), on trees in woods, Duck Mts., *M*.
U. florida Web. var. hirta Ach. (U. barbata var. hirta Fr.), Manitoba House and Porcupine Mts., *M*.
Xanthoria parietina (L.) Th. Fr. (Theloschistes parietinus Norm.), on stones, Lake Winnipegosis, *M*.; C. W. Lowe, 770.
X. polycarpa (Ehrb.) Oliv. (Theloschistes polycarpus Tuckerm.), on scrub oaks, Greenwood (Thos. Walker); on trunks, Red Deer River, Lake Winnipegosis, *M*.

REVIEW.

Fungi: Ascomycetes, Ustilaginales, Uredinales, by DAME HELEN GWYNNE-VAUGHAN, D.B.E., LL.D., D.Sc., F.L.S., Professor of Botany in the University of London. Demy 8vo, cloth, pp. xi + 232, with 196 figures in text. Price £1. 15*s*. net. Cambridge University Press.

It was long a reproach to mycologists in this country that there were few or no good English books on fungi. Students had to be referred to works in other languages or to translations of books which were often of relatively ancient date. The author has now removed this reproach, and all students of mycology will be grateful to her for this presentation of an eminently readable account of some of the most important groups of fungi. The book will be particularly welcome to university botanical students because it deals in a specially clear manner with the classification of the forms included in the Ascomycetes, Ustilaginales, and Uredinales. The book is written from the morphological standpoint with a strong cytological orientation, for although Chapter I deals with fungal saprophytism, parasitism, symbiosis, and with the reactions of fungi to stimuli, only the fringe of these interesting topics is touched upon. A clear idea of the morphology of the fungi, such as this book conveys, is essential to anyone who wishes to follow one of the many avenues of investigation now available in mycology, and it

would perhaps have made the book of undue length if some of these fascinating phases of the biology of the fungi had been explored in greater detail.

The author is a well-known worker on the cytology of the fungi, and her supreme interest in this aspect of mycology is evident throughout the book. She is an ardent believer in the existence of two nuclear fusions and two reduction processes in the life-cycle of the Ascomycetes, and is the founder of the term "brachymeiosis" to denote the third nuclear division in the ascus as described by her and others. Mention is made of the alternative view, that, like all other organisms of a sexual nature, the Ascomycetes possess only a single nuclear fusion and reduction process in their ontogeny. The author sums up this divergence of outlook as follows: "according to our present knowledge of the cytology of the Ascomycetes there are two nuclear fusions in the life-history of these plants," a statement which, in view of the large amount of recent work that points in the other direction, is somewhat surprising. However, as an account of the comparative morphology of the sexual organs of the Ascomycetes there is no book to approach it in excellence.

The chief innovation in the classification of the Ascomycetes is the institution of the group, Plectomycetes, to include the Plectascales (Endomycetaceae, Aspergillaceae, etc.), Erysiphales, and Exoascales. This is a very convenient arrangement, but its significance is uncertain, for, as the author emphasises, further investigation is required before much is known about the phylogenetic inter-relationships of the Ascomycetes. It is undoubtedly right to remove the Erysiphales from the Pyrenomycetes. In the general treatment of the Ascomycetes there are some notable omissions: for instance, there is no mention of such a common fungus as that causing apple canker.

Short chapters are devoted to the Ustilaginales and the Uredinales, but, apart from details of cytological development, the information is rather fragmentary. The occurrence of infection through the flowers in certain smut fungi of cereals is not mentioned, and there is only the barest reference to *Hemileia*, the most important rust genus in the tropics.

The letterpress and illustrations of the book are excellent. The wealth of figures is amazing, and they are beautifully executed, largely by the author herself. It is a special pleasure to see a reproduction of *Cyttaria Gunnii* from Berkeley. Unfortunately the price of the book is high (35*s.*), but it is indispensable to all serious students of fungi.

F. T. B.

PROCEEDINGS, 1922.

MEETING. UNIVERSITY COLLEGE, LONDON. *21st January.*

Dr W. Brown. On the Germination and Growth of Fungi at Various Temperatures and at Various Atmospheres.

Miss D. M. Cayley. Die-back of Stone Fruits due to *Diaporthe perniciosa* and the Behaviour of Monospore Cultures in Artificial Media.

Mr W. B. Crow. The Morphology and Affinities of *Leuconostoc mesenteroides*.

Mr W. J. Dowson. Michaelmas Daisy Wilt.

Dr M. C. Rayner. Obligate Symbiosis in *Calluna*.

MEETING. BOTANY SCHOOL, CAMBRIDGE. *18th March.*

Mrs M. N. Kidd. Diseases of Apples in storage.

Mr J. Line, M.A. The parasitism of *Nectria cinnabarina*.

Mr M. Mehta, M.Sc. Observations on the occurrence of wheat rusts near Cambridge.

Mr F. T. Brooks, M.A. and Mr C. G. Hansford, B.A. Mould growths on cold-store meat.

MOULD GROWTHS UPON COLD-STORE MEAT.

By F. T. Brooks, M.A. (*University Lecturer in Botany, Cambridge, and Food Investigation Board*),
and C. G. Hansford, B.A. (*Food Investigation Board*).

CONTENTS.

I. INTRODUCTION.

An investigation of the mould fungi which contaminate chilled and frozen meat was commenced in 1918 when considerable quantities of imported meat were found to be damaged in this manner, probably chiefly on account of the abnormally long periods of storage which war conditions necessitated. Since then, numerous specimens of mould growths upon cold-store meat have been examined, and investigations have been made concerning the conditions under which these moulds develop. In 1921 a report (3) upon the "Black Spot" of chilled and frozen meat was published (Special Report No. 6, Food Investigation Board), and the present account contains a description of the other moulds which have been encountered during the course of the work*. These researches have been carried out under the auspices of the Food Investigation Board of the Department of Scientific and Industrial Research.

With one exception, all the fungi described have been repeatedly observed during the last three years upon cold-store meat, and in view of the multiplicity of fungoid forms, it is somewhat remarkable that those which occur upon meat are so few in variety. Our observations agree well with those of Massee (12), but he described in detail only *Cladosporium herbarum*, the cause of "Black Spot." Some of the other forms he mentioned, e.g. *Penicillium glaucum*, *Mucor mucedo* and *Mucor racemosus* we have seen, but *Oospora carneola*, *Verticillium lateritium*, *Penicillium candidum* and *Phycomyces nitens* we have not seen, notwithstanding repeated search. Klein (10) referred

* We are indebted to Mrs M. N. Kidd for assistance during the earlier stages of this investigation.

the cause of "Black Spot" to *Oidium carnis* but this is doubtless another, but incorrect, name for *Cladosporium herbarum*. Tabor (17) has recently contended that "Black Spot" of meat may be produced by many different fungi, but in our experience there is no satisfactory evidence for this statement. The fact that he has invariably failed to obtain growth from "Black Spots" shows that his methods are imperfect, and his contention that the "Black Spots" are due to the death of various mould fungi in the meat cannot be substantiated. In practically every case that came under our observation, the "Black Spots" on meat contained living mycelium which gave rise, under suitable conditions, invariably to *Cladosporium herbarum*, and to no other fungus. Furthermore, the only fungus with which we have been able to reproduce "Black Spot" on meat in cold storage is *Cladosporium herbarum*. It often happens that other mould growths of a more superficial character, such as *Penicillium* and *Mucor*, are superimposed upon "Black Spot," but in no case have they had anything to do with the very well-defined trouble of "Black Spot."

While this work was in progress, Monvoisin (13) in France, was making a similar investigation unknown to us. He published a short paper, the results of which agree in the main with our observations. The fungi he specifically mentions as occurring on cold-store meat are *Thamnidium elegans*, *Mucor mucedo*, *Rhizopus* sp. and *Penicillium glaucum*. At a much earlier date, Talayract (18) had recorded the occurrence of *Penicillium*, *Sporotrichum*, *Mucor* spp., *Dematium*, and pink yeasts upon imported meat which he had seen in the London docks, the *Dematium* mentioned here being doubtless *Cladosporium herbarum*.

Quite recently another French worker, Bidault (2), has published a brief account of the moulds of frozen meat. The forms of commonest occurrence according to him are much the same as those found by us, but in our experience *Botrytis* spp. and *Stysanus stemonitis* have not been seen. On the other hand, some species commonly found by us are not recorded by him. Details of experiments on the growth of these moulds at low temperatures are not given, but he states that *Chaetostylum Fresenii* (= *Thamnidium chaetocladioides*) and *Hormodendron cladosporioides* (= *Cladosporium herbarum*) will grow slightly at − 10° C., and that others will grow between − 6° and 0° C.

It was shown in the previous report (3) that the "Black Spot" fungus possessed the remarkable property of growth at − 6° C. Another of these meat moulds, *Torula botryoides*, was also found to develop at this low temperature, and more recently certain others have given evidence of slight power of development at − 6° C. All these forms grow readily at 0° to 2° C., and perhaps

others that have not yet shown growth at $-6°$ C. will be found capable of development between $-6°$ and $0°$ C.; this will shortly be tested. Monvoisin (13) states that mould spores (species not stated) will not germinate under cold-storage conditions, but that these forms, if allowed to germinate for sixteen hours at ordinary temperature, will continue their growth in the cold-store and produce new sporing bodies in the course of four to five months. Monvoisin does not state definitely the forms with which he experimented, but he implies that they were the species mentioned above. Our own results show that the spores of *Cladosporium herbarum* germinate even at $-6°$ C., but that subsequent growth is more rapid if germination has taken place for a short period at ordinary temperature. Failure to get some of the other species to develop at $-6°$ C. may perhaps be due to the conditions of humidity being different from those in Monvoisin's experiments. There is no doubt that some of these mould contaminations are due to the meat being exposed to temperatures above $0°$ C., especially a few degrees higher than this, as at more enhanced temperatures bacterial growth is so vigorous that mould development is inhibited to a great extent. On the other hand, it has been shown that prolonged storage may induce the formation of certain of these mould growths, e.g. "Black Spot," even at several degrees below $0°$ C. Shorter storage at a temperature just below $0°$ C. will also give opportunity for the development of some of these moulds.

The spores of all mould fungi found on cold-store meat retain their vitality for long periods, several, notably *Cladosporium herbarum*, *Penicillium expansum* and *Thamnidium* spp., remaining alive after being subjected to a temperature of $-6°$ C. for two years. A period of three years at this temperature has, however, killed even these forms unless growth has already occurred in the cold store.

Other common mould fungi also retain their vitality for long periods at low temperatures. For instance, spores of *Botrytis cinerea*, *Aspergillus niger* and *Acrostalagmus cinnabarinus*, germinated after being kept for a year on the surface of culture media at $-6°$ C., but spores of *Cephalothecium roseum*, *Fusarium coeruleum* and *Rhizopus nigricans* were killed under these conditions. It is noteworthy that prolonged exposure to cold retards the rate of germination of mould spores, and that young mycelia are more quickly killed by low temperatures than are spores. Recent research has indicated that even thin-walled fungal spores retain their vitality for much longer periods than was formerly supposed, and the present results confirm this.

In the course of this work it has been necessary to undertake a systematic study of many strains of certain of these fungi

which occur upon meat and upon vegetable substrata, and the observations upon the differences between these closely related strains are recorded here.

Several of these fungi are of common occurrence as moulds upon different kinds of organic matter, e.g. *Cladosporium herbarum*, but three are apparently new to science. Some occur commonly as moulds upon vegetable debris within and in the vicinity of abattoirs, and it is likely that all so occur. The similarity of the types of mould occurring on meat imported from different countries is very striking, and point to the cosmopolitan distribution of these fungi.

II. *CLADOSPORIUM HERBARUM.*

This fungus has been shown to be the cause of the trouble known in the frozen meat trade as "Black Spot." Several strains isolated from different kinds of meat have been proved to possess the power of growth below freezing point. Strains of this fungus have also been isolated from other sources, chiefly vegetable substrata, and some of these are also able to grow at $-6°$ C. For comparison, cultures of various species of *Cladosporium* were obtained from the Centraalbureau voor Schimmelcultures, Amsterdam. These were:

C. herbarum (No. 43)	*C. epiphyllum* (No. 44)
C. Aphidis (No. 42)	*C. carpophilum* (No. 47),

also *C. butryi* and *C. cucumerinum*, neither of which could be induced to fructify. In this connection it is noteworthy that other forms occasionally degenerated in the course of the work when cultivated for several generations on meat extract-peptone-agar.

In a paper on the mould-growths of frozen meat, Monvoisin (13) makes no special mention of *Cladosporium*. Bidault (2) records both *Cladosporium herbarum* and *Hormodendron cladosporioides* on frozen meat, but, for reasons which will be given later, we consider these to be identical.

In connection with the identification of the fungus causing "Black Spot" of meat, it was necessary to examine critically many closely related forms of *Cladosporium*. One of the results of this investigation has been to show that many so-called species of *Cladosporium* are not really specifically distinct from *C. herbarum*, but are only slightly different strains of the same fungus.

It is not only on meat that *Cladosporium herbarum* causes black spots. In September 1921, one of the writers saw dead fronds of the seaweed *Laminaria digitata* covered with black spots which to the naked eye appeared indistinguishable from

the "Black Spot" of meat (Fig. 1). Upon isolation, it was found that the cause of the black spots on the seaweed was also *Cladosporium herbarum*. The texture of such a seaweed is not unlike that of the connective tissue of meat upon which black spots are most prone to develop, and, as in the latter, the discoloration is due to the dark hyphae of the fungus ramifying in the tissues.

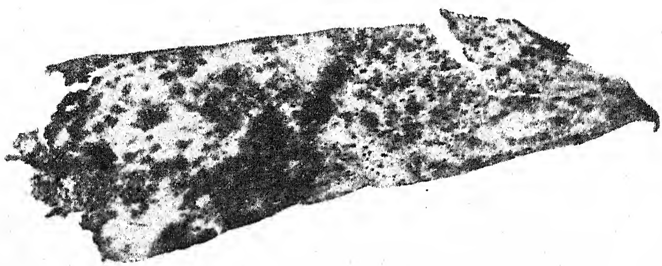


Fig. 1. "Black spot" on *Laminaria digitata*.

In view of growth proceeding at as low a temperature as $-6°$ C. it is clear that the sap of this fungus must possess a high osmotic concentration. The hyphae are narrow and it is difficult to observe plasmolytic phenomena in them, but immersion in a 15 % solution of calcium chloride undoubtedly causes plasmolysis while immersion in a 10 % solution is without effect.

The following is chiefly a systematic comparison of the characters of the different forms of *Cladosporium* isolated from meat and from vegetable sources.

I. Morphological characters, etc.

The following remarks apply to all strains used during this work. Each strain is denoted by a letter or number.

1. *Germination of Spores.*

The spores swell and then put out one, or sometimes two, germ tubes. These usually give rise to a branched mycelium, but occasionally when the conidium has given rise to two germ tubes, one of these forms a short conidiophore of the usual *Hormodendron* type.

2. *Hyphae.*

The hyphae are uniform in size and appearance in all strains, varying from 3–7 μ in diameter, and are septate at short intervals. In colour they vary from hyaline to almost black, according to age and strain. The length of time taken by the hyphae to turn dark olive varies with the strain, some, e.g. strain *S*, taking a very short time, others, e.g. *Z*, taking much longer. This influences the macroscopic appearance of the colonies, those of *S* being dark almost to the extreme edge of the colony, while those of *Z* show a distinct light margin of varying width.

Some strains, particularly *Z*, 60, 119A, when grown on Dox's medium, show fine, hyaline hyphae coiled in a peculiar manner. These arise as lateral branches of the normal hyphae. Other strains do not show this peculiarity.

3. *Conidiophores.*

The conidiophores arise as branches from the vegetative hyphae and grow erect into the air. They are septate and usually dark in colour, though in some strains they are comparatively light.

The present strains can be grouped into three classes, according to the length of the conidiophores, thus:

(*a*)	Short	conidiophores	(less than 100 μ)	—*Z*, 43, 108A, etc.
(*b*)	Medium	,,	(100–250 μ)	—44.
(*c*)	Long	,,	(over 250 μ)	—*S*, 110.

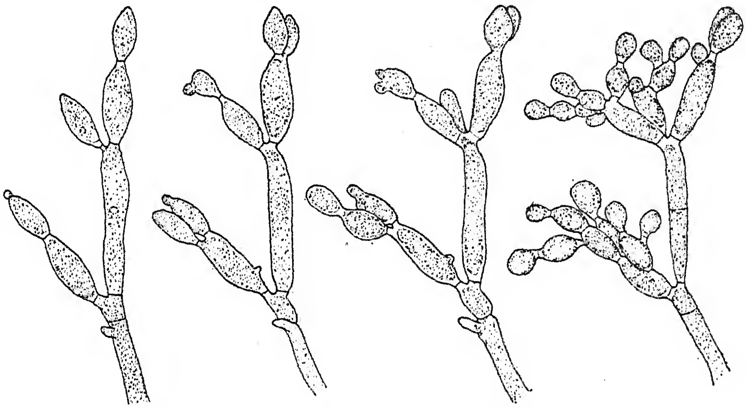
These classes are arbitrary and all gradations occur between the shortest and longest. This classification is based on a series of cultures in Petri dishes, on potato agar in the light at laboratory temperature. The width of the conidiophore is approximately that of the hyphae from which it arises.

The differentiation of the conidiophores from the vegetative mycelium varies in different strains. In *S*, the conidiophores are very distinct from the mycelium, whereas in *Z* the conidiophores are not differentiated. This distinction is more marked in those strains with long, unbranched conidiophores. In some strains the sterile part of the conidiophore is much branched, thus resembling the vegetative mycelium. In strain *S* the conidiophores are invariably unbranched, except at the apex where the head of conidia is formed.

4. *Formation of Conidia.*

The tip of the conidiophore is cut off by a wall to form the first conidium, this being invariably of the large type. The cell of the conidiophore immediately behind the first conidium may or may not grow out to form a second conidium, lateral to the

first. In nature each conidiophore usually bears a few large spores, but under culture conditions these large spores bud forth, giving rise to chains of smaller spores, the so-called *Hormodendron* stage. The youngest conidium is that at the distal end of the chain, the large conidia next the conidiophore being the oldest. Each conidium of a chain arises as a small bud on that immediately behind (cf. Fig. 2).



(1) 10 a.m. Mon. (2) 3.0 p.m. Mon. (3) 6 p.m. Mon. (4) 9.0 a.m. Tues.

Fig. 2. Formation of conidia of *Cladosporium herbarum*. (Hanging drop culture). × 900.

While still quite small, this bud is cut off by a membrane from the parent conidium, and continues to enlarge. The membrane between the young conidium and its parent is thickened from both sides simultaneously with the growth of the former, until finally, under certain conditions of microscope illumination, it appears as a small intercalary piece (cf. Fig. 3). On separation of the conidia, these "intercalary pieces" break asunder, along the line of the original membrane between the two conidia. Thus the majority of the conidia when separated, show a small stalk at each end, giving them a somewhat lemon-shaped appearance.

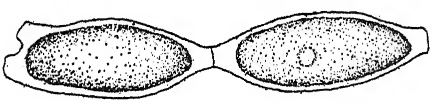


Fig. 3. Conidia of *C. herbarum* showing thickened end walls. × 3100.

The method of spore formation is the same in all the present series of forms.

5. *Conidia.*

As mentioned above, the conidia in artificial cultures differ considerably from those formed in nature. Upon vegetable debris in nature, the conidia are almost entirely of the large variety, while in cultures the large conidia are masked by the enormous numbers of small conidia formed by the process of budding described above. In culture, the conidia are in long branched chains, forming a more or less dense head at the end of the conidiophore. The number and length of these chains of small conidia is an index of the amount of budding that has taken place, and has a marked effect on the appearance of the conidiophore as seen intact under the microscope. In some strains, as *S*, the conidiophore terminates in a dense mass of chains of small conidia, while in other strains, as *Z*, the process of budding is much restricted, the conidiophore being terminated only by a small head of conidia. The budding influences the percentage of large conidia present, this being much greater in *Z* than in *S*.

The conidia vary greatly in size, from small spherical spores of about $4\,\mu$ in diameter, to large cylindrical conidia up to $25\,\mu \times 4\text{–}5\,\mu$. The large basal conidia of the "head" merge gradually into the small spherical conidia of the distal parts of the chains. The large conidia are more or less cylindrical, tapering slightly at the ends, and may be 1–3 times septate, the septation being more frequent in old cultures.

According to Saccardo (15) and Rabenhorst (14) the large conidia of *C. herbarum* are constricted at the septa, but while this constriction is common in nature, though by no means universal, it is exceptional in artificial cultures, and is not characteristic of any particular strain. The same authors state that the walls of the conidia of a form (*Vincetoxici*) of *C. herbarum* are granular to echinulate, but in our cultures indications of a roughness of the conidial walls were very rare, although the walls of the conidia originally formed in nature by some strains were certainly rough.

The colour of the conidia as seen under the microscope varies with their age, the largest (i.e. also the oldest) conidia being darker in colour than the small conidia of the distal ends of the chains. In some strains, as *Z*, the conidia never become very dark in colour, while in *S* they become almost black. Every intermediate between these two extremes is present.

A minor point of difference between the two extreme strains *S* and *Z* is that the latter never formed truly spherical spores, while in *S* the fourth or fifth conidium from the base of the "head" was practically spherical.

II. Macroscopic Characters of Strains.

Although the various isolations approach each other so as to be almost indistinguishable under the microscope, to the naked eye there are considerable differences between them as indicated in the table, p. 125. Few cultures of the fungus isolated during the present work were absolutely identical in appearance. The strains were grown on Dox's medium with the full amount of sugar (30 gms. per litre). This medium proved to be the best for differentiating between the various strains, the cultures being compared at the end of two months' growth. Growth on this medium was luxuriant, and two characters were used to differentiate the strains:

(1) Colour.

(2) Texture of colony—whether "woolly" or not.

The "woolly" texture of some strains is due to the aerial growth of sterile mycelium—the hyphae being often very fine and almost hyaline—forming a layer over the conidiophores. The characters of the various strains were much the same when grown upon steamed potato.

III. Physiological Characters of Strains.

1. *Influence of Temperature.*

The approximate range of temperature within which each strain would grow was determined. The different strains show considerable divergence in this respect, and the grouping of the strains, according to this character, does not follow the arrangement according to other characters; the table given below is an attempt to classify them according to both.

As already recorded, some strains proved capable of growth below freezing point, at $-6°$ C., and probably others which would not grow at this temperature could develop at a slightly higher temperature, as all the strains isolated from "Black Spot" on meat in cold storage grew well at $2°$ C. Temporary freezing up to a month at $-6°$ C. had no effect on the rate or percentage of germination of the spores subsequently tested at room temperature, but prolonged freezing at $-6°$ C. eventually killed the spores of most strains, except such as proved capable of germination and growth at this temperature.

Temporary freezing (up to three weeks) of the vegetative mycelium of strain *S* had no permanently adverse effect, beyond greatly retarding growth.

2. *Influence of Light.*

With a view to the possibility of distinguishing forms of *Cladosporium* from those of *Hormodendron*, according to the

method of Schostakowitsch (16), a series of cultures was made in Petri dishes and exposed to illumination from one side only. A few strains showed a positive reaction to light, the conidiophores bending towards the source of light. The strains showing this characteristic were *S*, 102D, 103B, 113, all of which were originally isolated from meat in cold storage. Several other strains isolated from similar sources showed no reaction to light.

3. *Influence of increased concentration of mineral salts.*

Schostakowitsch (16) states that he was able to distinguish the two forms *Hormodendron* and *Cladosporium* by their characters when grown in solutions containing a high concentration of potassium nitrate. A series of cultures of the two strains *S* and 43 was made in a nutritive solution, to which various amounts of KNO_3 were added. Both strains grew in all strengths of KNO_3 up to saturation, and the differences between the two strains were much less in the more concentrated solutions than under more normal cultural conditions.

IV. Relation of *Cladosporium* to *Hormodendron*.

According to Bancroft (1) conidia of the *Cladosporium* type when germinated at a low temperature (below 56° F.), form a mycelium which produces other conidia of the same type. If germinated at a higher temperature (60° F. or above) he states that the conidia formed belong to the *Hormodendron* type. In the course of the present work it was found that Bancroft's statements could not be confirmed for any of the strains used. The "*Hormodendron*" stage was produced in every culture grown at low as well as at high temperatures on both solid and liquid media. Even at − 6° C. "Black Spot" produced by artificial inoculation of meat gave rise to many *Hormodendron* spores, although the proportion of large spores of *Cladosporium* type was greater than at ordinary temperature.

On examination of the present series of cultures it was found that the distinction between *Cladosporium* and "*Hormodendron*" was merely a question of the amount and character of the budding of the first-formed conidia as described above, and that the two forms merged gradually one into the other.

It is noteworthy that in nature the "*Hormodendron*" type is less common than the *Cladosporium*. In our experience the strains isolated from the latter type do not differ more from those isolated from the former type, than they differ among themselves. Thus the claim of Schostakowitsch (16) that he was able to differentiate the two types by

(*a*) the positive heliotropism of *Hormodendron*,

(*b*) the rough conidial walls of *Cladosporium*,
(*c*) the production of conidia by *Hormodendron* in a higher concentration of KNO_3 than *Cladosporium*,

is not supported by the present work.

No indication of any connection of *Cladosporium herbarum* with *Dematium pullulans* as mentioned by Delacroix and Maublanc (4) was observed in the course of this work, neither was there any evidence of a perithecial form as described by Janczewski (7-9).

V. Discussion.

Lindau in Rabenhorst's *Kryptogamen-Flora* in a note on the genus *Cladosporium*, mentions the great range of the species *C. herbarum*, and the consequent difficulty in diagnosing both this species and the whole genus. In a note on the "species" *C. epiphyllum* he expresses a doubt as to whether it is distinct from *C. herbarum*, and says that the two are often confused.

In the present work it was impossible to distinguish the Dutch culture of *C. epiphyllum* from some of the other forms. The whole of the present series of forms with the exception of No. 47 (*C. carpophilum* from Holland) were so closely allied in cultural and microscopic characters that separation into distinct species was impossible.

In Rabenhorst's *Kryptogamen-Flora* and also in Saccardo's *Sylloge*, the various "species" of *Cladosporium* are grouped more or less according to the substratum upon which they occur. This is very unsatisfactory, especially in view of the enormous range of hosts of the single species *C. herbarum*, and it is more than probable, in the light of the present work, that the great majority of the "species" described in these works ought to be included in *C. herbarum*. The diagnoses of many of the species are so vague that they cannot be taken seriously into consideration. Certainly, as a result of the present work, the two "species" *C. epiphyllum* and *C. Aphidis* must be included as synonyms of *C. herbarum*. These forms were sent from the Centraalbureau voor Schimmelcultures, Amsterdam, and represent, in our opinion, merely strains of the species *C. herbarum*.

On the other hand, the culture of *C. carpophilum* from the same source differed so greatly from all other strains that it must be retained as a distinct species. Thus, in view of the present work, the species of *Cladosporium* should be revised entirely, and diagnosed afresh, not only on the basis of their host plants and morphological characters as found in nature, but also upon their cultural characters.

VI. Table of differences between strains of *Cladosporium herbarum*.

The various strains included in the table on the opposite page are arranged as far as possible as intermediates between the two extremes, *S* and *Z*. Many other strains are not included, on account of their extreme "woolliness" on all media, which rendered it difficult to group them in this series. The table illustrates the wide range of the single species *C. herbarum*. The classification is based upon the following points, which were selected as the most definite criteria:

(1) colour and texture of colonies on Dox's medium,
(2) ,, ,, ,, steamed potato,
(3) length of conidiophores,
(4) branching of "stalk" of conidiophore,
(5) whether "heads" of conidia are dense or not (i.e. an index of the relative amount of budding of conidia),
(6) temperature relations,
(7) reaction to light.

III. *SPOROTRICHUM CARNIS* n.sp.

This fungus was more frequently found upon all kinds of meat in cold storage than any other. It occurs in the form of innumerable white, slightly woolly patches, small in extent, and is the commonest form of "white mould" known to the meat trade. The growth of this fungus on meat is entirely superficial. It was present to some extent at any rate upon practically every sample of mouldy meat examined, although "Black Spot" caused by *Cladosporium herbarum* was sometimes more abundant. Talayract (18) mentions the occurrence of *Sporotrichum* upon chilled meat, but does not say what the species was.

Many slightly-differing strains were isolated from contaminated meat, but it is considered that all these belong to one species, a new one, *Sporotrichum carnis*. For comparison, cultures of *S. bombycinum* and *S. globuliferum* were obtained from the Centraalbureau voor Schimmelcultures, Amsterdam.

A form of *Sporotrichum*, indistinguishable from *S. carnis*, has recently been found to be of fairly common occurrence in slime fluxes of trees by Mr L. Ogilvy working at Cambridge, and one of us working in a Danish laboratory a short time ago encountered this fungus as a laboratory contamination.

Table of differences between strains of Cladosporium herbarum.

Strain	Origin	Macroscopic appearance on *Dox's medium* (two months' growth)	Length of Conidiophores	"Heads" of Conidia	Branching of Conidiophores	Range of temperature within which growth occurs*	Macroscopic appearance on potato chunks	Heliotropism
S	Meat in cold storage	Green brown, not woolly	Long	Very dense	Not branched	−6° C. 20° C.	Almost black, not woolly	+heliotropic
103B	,, ,,	,, ,,	,,	,,	,,	−6° C. 20° C.	,, ,,	,,
113	,, ,,	,, ,,	,,	,,	,,	2° C. 20° C.	,, ,,	,,
50B	*C. herbarum*? from Miss Smith, South Kensington	,, ,,	Medium-long	,,	Occas. branched	2° C. 25° C.	,, ,,	Not heliotropic
102D	Meat in cold storage	,, ,,	Long	,,	Often branched	?	,, slightly woolly	+heliotropic
114B	,, ,,	,, ,,	Medium-long	,,	,,	−6° C. 25° C.	Grey-green, very woolly	Not heliotropic
112	,, ,,	Green brown, woolly	,, very long	,,	Branched	2° C. 20° C.	,, ,,	,,
110	,, ,,	Bright green, slightly woolly	Very long	Not as dense as *S*	,,	2° C. 20° C.	Almost black, slightly woolly	,,
31	Black Currant twig	Green-black, not woolly	Medium	Very dense	Much branched	2° C. 25° C.	Black, light margin, slightly woolly	,,
44	"*C. epiphyllum*" from Holland	Bright green, not woolly	,,	,,	Branched	2° C. 25° C.	Green, very woolly	,,
37	Honeydew in green-house	,, ,,	Short-medium	Not as dense as *S*	,,	2° C. 30° C.	Almost black, not woolly	,,
54	Tomato fruit	Green-black ,,	,,	Very dense	,,	?	Light green, very woolly	,,
42	"*C. aphidis*" from Holland	Green-grey, slightly woolly	,,	Lax	Occas. branched	2° C. 20° C.	Green-brown, slightly woolly	,,
43	"*C. herbarum*" from Holland	Green-brown ,,	Very short	,,	Not branched	2° C. 30° C.	,, not woolly	,,
55	Maize shoot	Green-brown, woolly	Short	,,	Occas. branched	2° C. 25° C.	Green, woolly	,,
62	Wheat spikelet	,, ,,	Medium	Dense	,,	?	Green-brown, slightly woolly	,,
60	Dead leaves	Light green-grey, woolly	Short	Lax	Not branched	2° C. 25° C.	Grey-brown, very woolly	,,
108A	Meat in cold storage	Green, very woolly	,,	,,	,,	2° C. 25° C.	,, slightly woolly	,,
119A	,, ,,	Black, light margin ,woolly	,,	,,	,,	?	Green, slightly woolly	,,
Z	,, ,,	Green-black, slightly woolly	,,	,,	,,	−6° C. 25° C.	Green-brown, not woolly	,,

* The lower temperature is not necessarily the minimum.

I. Microscopical Characters.

The following remarks apply to all strains of *Sporotrichum carnis* used in this work, except where otherwise stated. The various strains are denoted either by a letter or a number.

1. *Germination of the spores.*

The spores swell considerably, each putting out one or two germ tubes, which give rise to a branched mycelium.

2. *Hyphae.*

The hyphae are very narrow, about 1 μ in diameter, and invariably hyaline. On some agar media the hyphae inside the medium differ from the normal type, being rather wider, and distinctly vacuolate. In the normal hyphae the septa are very obscure, but in these submerged hyphae the septa are more prominent. On agar the hyphae are usually straight, giving off branches almost at right angles to the parent hyphae.

The few strains which grow at 30° C. form peculiar stromatic colonies, consisting of swollen hyphae, the cells being very short and almost spherical. There is no penetration of the medium at this temperature as there is at ordinary temperatures.

3. *Formation of conidia* (Fig. 4).

(*a*) *Sporotrichum carnis.* Aerial branches arise from the vegetative mycelium, 30–50 μ in length. On these, other short branches arise, often in twos and threes, which may branch again. The branches are cut off by septa from the parent hypha, and the distal parts of the whole system of branches segment into short, cylindrical cells, 3–5 μ long. These cells form conidia, the apical portion of each swelling considerably, and their walls, especially the transverse wall at the base, thicken. Those cells of the conidiophore and its branches which do not form conidia disorganise, leaving nothing but the walls, which are almost invisible. The conidia are easily detached, and on mounting a portion of an old colony, a mass of spores is seen, with only occasional portions of hyphal walls.

(*b*) *Sporotrichum globuliferum* (from Amsterdam). As shown in Fig. 5, the conidiophore of *Sporotrichum globuliferum* differs greatly in appearance from that of the species isolated from meat. Long, aerial branches arise from the vegetative mycelium, many remaining sterile and contributing to the woolly appearance of the colonies, while others develop small groups of conidia at their ends and on short lateral branches. The conidia are both terminal and lateral on short sterigmata, those at the apex of the conidiophore being the youngest. This method of spore formation is distinct from that of *Sporotrichum carnis*.

4. *Conidia.*

The conidia of *S. carnis* vary greatly in size and shape. The majority, owing to their peculiar method of formation, are

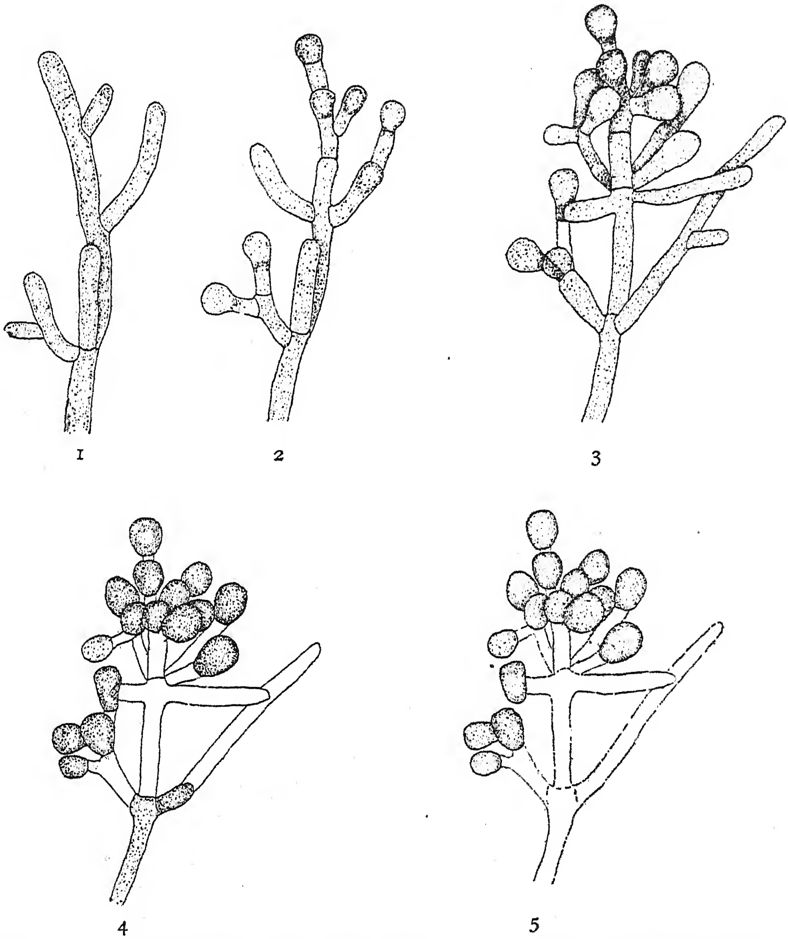


Fig. 4. Spore formation of *Sporotrichum carnis*. 1, young conidiophore from hanging drop culture, 48 hours old; 2, same, after a further 12 hours; 3, same, after a further 12 hours; 4, same as 3, 48 hours later; 5, same as 4, 48 hours later. × 2060.

somewhat pear-shaped, but others approximate to spherical. All the strains form hyaline conidia varying from 2–5 μ in length.

II. Macroscopic characters of strains of *S. carnis*.

The strains were cultivated on various media of which Dox's agar (containing half the usual amount of sugar), Sabouraud's glucose agar, and potato chunks were selected as best. On these media, especially on the second, the various strains, even when young, show marked differences. All are more or less white when young, but some show a peculiar yellow or orange discolouration inside the medium, which is absent from others. When the colonies are old, the aerial portions differ greatly in colour, varying in different strains from white to brown. Some strains are considerably more woolly in culture than others, especially on potato chunks.

III. Physiological characters (*S. carnis*).

(*a*) *Chemical.* The various isolations were grown in 4 % solutions of sugar to which peptone and litmus had been added.

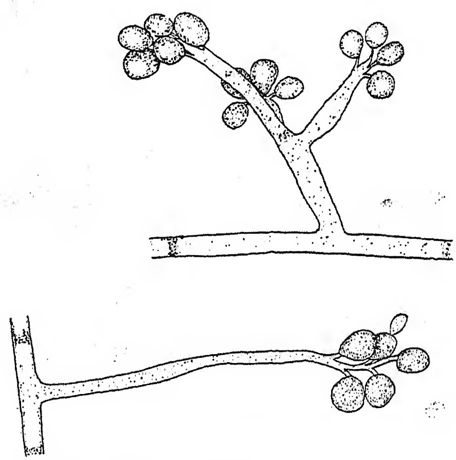


Fig. 5. *Sporotrichum globuliferum* conidiophores. × 2060.

They showed no great differences in their fermentation properties, all fermenting glucose, maltose, and laevulose, though the amount of acid produced varied to some extent. One or two forms also fermented sucrose. Some forms, especially those which showed a yellow discolouration of ordinary media, produced a yellow or orange pigment which diffused through the liquid. Three forms produced a dark-brown pigment instead of a yellow, and in one the litmus was bleached when the cultures were kept a month.

(*b*) *Temperature relations.* The forms were grown at different temperatures. Very slight indications of growth on artificial media at − 6° C. have been obtained in some strains after long periods, and as the majority of forms develop well at 2° C., it is likely that better growth occurs just below 0° C. than at − 6° C. The large white spots sometimes seen on meat have probably arisen through exposure to temperatures round about freezing point; there is no indication yet that such large growths would develop at − 6° C.

IV. Cultural differences of strains of *S. carnis*.

Scarcely any two isolations appeared identical in culture, but they can be arranged conveniently in four groups, according to their macroscopic appearance on Sabouraud's glucose agar, the medium on which they grow best. The microscopical characters of the strains are so similar as to be of no value for differentiating them.

1. *F Group*: comprising forms *F*, 121A, 104B, all isolated from meat in cold storage, and *L*, isolated from a Petri dish exposed in an abattoir in the Argentine.

This group is distinguished by its rather smooth colonies, which are not heaped up on the surface of the medium as in the next group, and by the development of a yellow pigment on almost all media used.

2. *W Group*: comprising forms *W*, 102E, 120B, 110A, all isolated from meat in cold storage.

These are very closely related and are characterised by their colonies being usually heaped up on the surface of the medium. In colour they vary from white to brown, and they produce no yellow pigment in the medium, as in the preceding group. Instead, in some liquid cultures they produce a dark brown pigment, diffusing through the liquid.

3. *"Woolly" Group*: comprising 118D, 120C, 103A, 101A, 104A, all isolated from meat in cold storage.

The extreme "woolliness" of these strains on all media distinguishes them from the other groups. The colonies are dirty brown in colour. These strains produce no yellow pigment in the medium, but some produce the dark brown pigment noted under the preceding group.

4. 119C *Group*: comprising 119C and 115G, isolated from meat.

On all media used these strains have very dense, smooth colonies, quite different from other groups. The colonies show

alternating coloured and white zones, the colour varying from pink to buff. On some media 115G develops a dark red colour.

It may be mentioned that *Sporotrichum globuliferum* differs both microscopically and macroscopically from all strains of *S. carnis*. On all media the colonies were light yellow in colour and extremely woolly, and in liquid cultures this fungus developed a yellow or orange pigment, which diffused into the medium.

V. Discussion.

The forms isolated from meat, although falling into the above groups may yet be classified as one species, as under the microscope no differences can be seen which would justify separation into distinct species.

As far as one can determine from the meagre diagnoses of other species of *Sporotrichum* given in Rabenhorst's *Kryptogamen-Flora* and in Saccardo's *Sylloge*, the present species differs from all others previously described. The diagnoses of the species given in these books are often so inadequate that identification is impossible, and unless re-diagnosis is possible it would be better to discard them. Diagnosis of such species should be based, not only on the characters exhibited when growing on the original substratum, but also on cultural characters on standard media under controlled conditions.

VI. Comparison with other Sporotrichums spp.

The diagnosis of the genus in Rabenhorst's *Kryptogamen-Flora* is as follows:

Hyphae: forming a "turf," septate or not septate, creeping or decumbent, irregularly but never verticillately branched; branches usually branched again.

Conidiophores: hardly differentiated, at most very like the ordinary side branches.

Conidia: lateral or terminal on the hyphae or on small branches, usually very numerous, may or may not have well-developed sterigmata, oval or spherical, hyaline or slightly coloured, very small.

In a note on the genus, Lindau says that "only in a few cases are the conidiophores erect, thereby being distinguished from the side branches; the spores are usually produced on the creeping mycelium, which soon disappears. Then the colony consists of masses of spores and remains of hyphae. The spores are produced terminally but through growth of the hyphae soon become lateral; the spores are often situated on small protuberances of the hyphae."

This method of spore formation is much the same as that

described for *S. globuliferum*, but is very different from that of *S. carnis*.

To this method of spore formation given in Rabenhorst, must be added a second, that of the present species as described above.

The diagnosis of this new species is as follows:

Sporotrichum carnis n.sp.*

Forming circular colonies, white, closely adpressed to the substratum.

Hyphae creeping, interwoven, branched, septate, septa very obscure, hyaline, 1–2 μ wide.

Conidiophores not well differentiated, much branched, hyaline.

Conidia formed laterally or terminally from slightly swollen distal cells of branches of conidiophores, hyaline, 2–5 μ × 2–4 μ, oval-pyriform. The conidiophores soon disorganise after formation of conidia. In artificial culture the colonies may appear coloured, varying from pale yellow to dark reddish brown and may be compact or woolly.

Habitat on meat which has been kept in cold storage.

IV. *TORULA BOTRYOIDES*, n.sp.

This fungus was first isolated in May 1918 from a halibut which had been kept in cold storage. The fish was sent to one of the writers in connection with another enquiry then in progress; upon arrival it was apparently free from moulds. Within a few days, however, whitish fluffy growths began to appear upon it, especially around the mouth and gills, notwithstanding the fact that the fish was kept in a refrigerator below 0° C. except when being examined. The same fungus was subsequently isolated from beef, mutton, rabbits, and sausages which had been kept in cold storage. On meat it produced a greyish-white, rather woolly growth, quite distinct in appearance from *Sporotrichum carnis*.

I. MICROSCOPIC CHARACTERS.

1. *Germination of spores.*

The spores swell considerably and produce germ tubes, which give rise to a mycelium of branched hyphae. In this connection

* *Sporotrichum carnis* sp.nov.

Coloniis candidis substrato arcte adpressis; hyphis repentibus, intertextis, ramosis septatis (septis valde inconspicuis), hyalinis, 1–2 μ latis; conidiophoris haud bene evolutis, valde ramosis, hyalinis; conidiis in ramulorum tumidulis apicibus pleurogenis vel acrogenis, hyalinis, 2–5 μ × 2–4 μ, ovali-pyriformibus. Conidiophoris post conidia effecta mox dilabentibus. Coloniae in mediis nutrientibus cultae diverse coloratae, interdum pallide luteae interdum fusco-rubello-brunneae, et congestae vel flocculosae sunt.

Hab. Ad carnem in frigidariis asservatam.

We are indebted to Mr Gepp and Mr Ramsbottom of the British Museum for assistance in drawing up the Latin diagnoses.

it may be noted that no indication of the formation of a dense aggregation of cells was obtained, as described by Kr. Høye (6) for *Torula epizoa*, a common fungus on salted cod in Norway. Even when sown in fish extract with 10 % salt added, the spores germinated in the usual manner.

2. *Hyphae.*

The hyphae are hyaline to light olive in colour, septate at intervals, the septa being rather difficult to observe. The hyphae vary in width from 2–5 μ.

3. *Formation of spores.*

The "conidiophores" are very variable, and under certain conditions may be almost entirely absent. In all cultures the

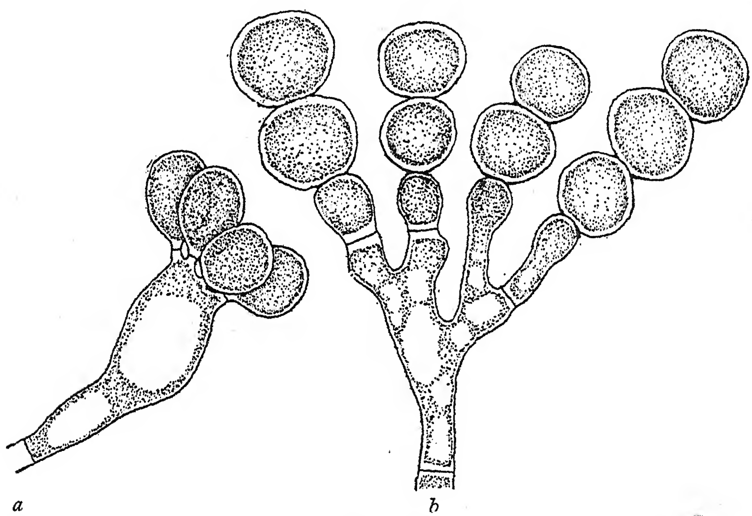


Fig. 6. *Torula botryoides*, n.sp. *a*, conidiophore from culture in liquid fish extract, ×1500; *b*, conidiophore from culture on steamed potato showing method of spore-formation, ×2300.

spores are formed not only in dense heads on the conidiophores but also laterally in small groups of two or three along the ordinary hyphae. The "conidiophores" are never very distinct from the vegetative hyphae, and are usually much branched (Fig. 6). The ends of the branches of the conidiophores are more or less swollen, depending on the conditions of growth. On potato chunks at laboratory temperature the ends of the conidiophores form pronounced sterigmata, somewhat resembling those of *Penicillium*, and from which the conidia are abstricted, in long chains, as in *Penicillium*. On agar slopes at

2° C. the sterigmata are much less pronounced and the conidia appear to be borne in dense heads on the ends of the conidiophore. These apparent heads of conidia are made up of short chains, the base of each chain being attached to the conidiophore by a sterigma (Fig. 7).

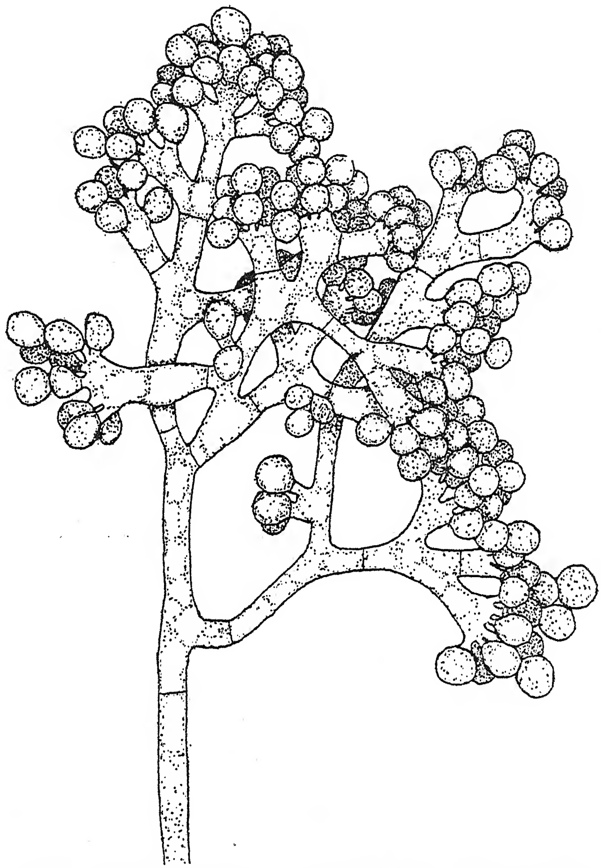


Fig. 7. *Torula botryoides*, n.sp. Conidiophore from culture on agar at 2° C. × 600.

4. *Spores.*

The spores are spherical to oval in shape, 4–8 μ × 4–6 μ in size, the mean size of the conidia being very constant under all conditions of growth. When young they are hyaline, but become olivaceous when older. The chains of conidia easily break up into separate spores. The walls are smooth.

II. Macroscopic Characters.

The fungus does not spore at all well on potato agar at ordinary temperatures. The growth is chiefly vegetative, dark olive in colour and almost entirely within the medium. On other solid media, e.g. steamed carrot or potato, growth is more profuse and greyish in colour, and the colonies develop masses of spores. The various isolations are uniform in appearance under cultural conditions, showing a great contrast to those of *Sporotrichum carnis* and *Cladosporium herbarum*.

III. Physiological Characters.

The various isolations of this fungus were grown at temperatures of − 6, 2, 12, 25, 30° C. No growth took place at 25° or 30° C. At the ordinary laboratory temperature growth was fair but resulted in the formation of few spores upon potato agar, the cultures consisting almost entirely of mycelium within the agar slants. At 2° C. a copious aerial growth was produced upon the same medium, giving the culture a greyish-white appearance, whereas at laboratory temperature, the fungus was dull brown or black in colour. The fungus formed an abundance of spores on the agar cultures at 2° C., these being produced in groups of short chains on much branched conidiophores, as well as in isolated groups along the hyphae. Growth occurred at − 6° C., but was very slow, even slower than in *Cladosporium herbarum*.

IV. Discussion.

The systematic position of this fungus is obscure. On fish and meat, from which it was originally isolated, it was a greyish-white, woolly mould. In cultures on potato agar the colonies are brownish at ordinary temperature. In view of this, the fungus is considered to belong to the Dematiaceae, a conclusion supported by the formation of conidia which are hyaline to olivaceous in colour. The branched conidiophores with their sterigmata bearing spores, seem to be peculiar to this fungus, but for the present it is included in the genus *Torula*. The general appearance of the young conidiophores suggests the specific name *botryoides*. The diagnosis is as follows:

Torula botryoides n.sp.*

Colonies grey-white to fuscous, woolly, ¼–1" in diameter. *Hyphae* septate, hyaline to light olive, 2–5 μ wide.

* *Torula botryoides* sp.nov.

Coloniis cinereo-albis vel fuscis, lanosis, 0·7–2·5 cm. diam., hyphis septatis hyalinis vel pallide olivascentibus, 2–5 μ latis. Conidiophoris e mycelio haud diversis, valde ramosis; conidiis in catenulis e sterigmatibus vel in acervulis

Conidiophores not distinct from the vegetative mycelium, much branched.

Conidia produced basipetally in long chains from sterigmata, also in groups of 1–3 along hyphae, hyaline to olivaceous, $4–8\,\mu \times 4–6\,\mu$, spherical to oval. On potato agar at ordinary temperatures colonies brown-black, and partly sterile. On steamed potato or carrot the colonies are grey-white and spore freely.

Habitat on fish and meat kept in cold storage.

Kr. Høye (6) describes a species of *Torula*, *T. epizoa*, upon dried salted cod in Norway, causing brown spots on the fish. Experiments showed that its growth was much restricted if no salt were present in the medium. Its growth was best in fish extract containing 10 % of salt. The colonies found on dried fish consisted mainly of a dense layer of chains of spores abstricted from the mycelium. The present fungus, *T. botryoides*, shows none of the above characters. On meat in cold storage the fungus forms greyish-white, rather fluffy patches, and its growth in cultures is much restricted if salt is added to the medium. Høye describes a peculiar cellular stroma developed by his fungus when grown in cod-extract gelatine containing less than 10 % salt, hyphae being very feebly developed. No such mode of germination has been observed in *Torula botryoides* under any conditions. It is clear that the two species are distinct.

W. G. Farlow (5) describes a fungus *Oidium* (*Torula*) *pulvinatum*, also found on the surface of dried cod in America, causing brown spots, but his diagnosis is not applicable to *T. botryoides*, as he states that the spores of *T. pulvinatum* are only $3–5{\cdot}5\,\mu$ in diameter, and 12–15 in a chain, whereas the spores of *T. botryoides* are rather larger, and the chains may be much longer or absent. His drawing of a young conidiophore bears no resemblance to that of *T. botryoides*. *Oidium* (*Torula*) *pulvinatum* is probably identical with *Torula epizoa* but the diagnosis of these forms is inadequate.

V. *WARDOMYCES ANOMALA* n.gen. and n.sp.

This fungus was isolated once during the course of the investigation from a white, slightly woolly patch of mould on one of a consignment of skinned Australian rabbits which had been condemned on arrival here in consequence of serious contamina-

1–3nis e hypharum lateribus ortis, hyalinis vel olivascentibus, $4–8\,\mu \times 4–6\,\mu$, sphaericis vel ovalibus. Coloniae in agaro Solani tuberosi temperie normali cultae brunneo-atrae et partim steriles, in Solano cocto et in Dauco cinereo-albae et libere sporiferae sunt.

Hab. Ad carnem in frigidariis asservatam.

tion by mould growths. On the rabbit, this particular mould was almost indistinguishable from *Sporotrichum carnis*, but upon isolation it showed quite different microscopic characters.

The spores germinate to form a branched mycelium of hyaline hyphae 2–4 μ wide. The conidiophores arise as short, lateral branches, 15–25 μ long, from the vegetative hyphae; they remain hyaline and become septate with age. Some conidiophores are unbranched and form rarely short chains of two or three conidia, the distal conidium being the oldest; others branch repeatedly and form heads of spores which usually arise separately, although under certain cultural conditions two spores are formed occasionally in a chain. Two or three spores are often produced on each of the terminal cells of the branched conidiophore, one spore being formed terminally and the others in succession laterally (Figs. 8–10).

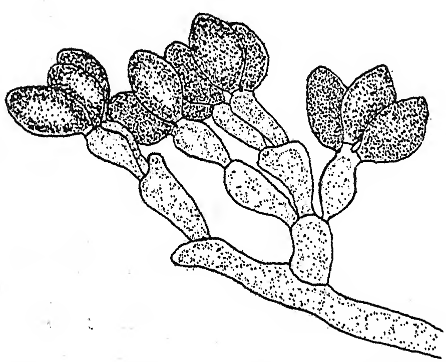


Fig. 8. Conidiophore of *Wardomyces anomala*, n.sp., from culture on agar. × 1500.

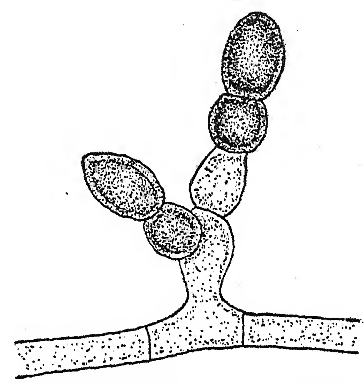
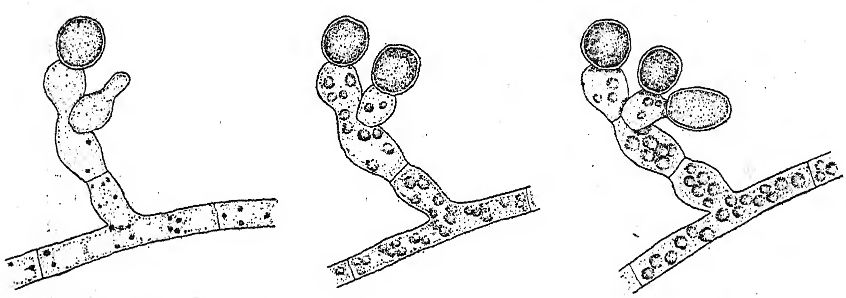


Fig. 9. Conidiophore of *Wardomyces anomala* n.sp., showing short spore chains. × 2300.



a *b* *c*

Fig. 10. Spore formation of *Wardomyces anomala*, n.sp. (*a*) Stage 1, from drop-culture 3 days old, × 1500. (*b*) Stage 2, 24 hours after stage 1, × 1500. (*c*) Stage 3, 24 hours after stage 2, × 1500.

The conidia are dark brown to black in colour, and vary in shape from sub-spherical to oval, with slightly pointed ends. They are 5–8 $\mu \times$ 4–6 μ in size, with smooth walls which are almost opaque. The fungus grows well on the usual artificial media at ordinary temperature, but although isolated from rabbits which had been kept in cold storage does not grow at temperatures just above freezing point.

This fungus appears to be the type of a new genus of the Dematiaceae, the characteristic feature being the successive lateral proliferations of the basal cells of the conidiophores. The genus is named *Wardomyces* in memory of the late Prof. Marshall Ward.

Wardomyces n.gen.*

Mycelium creeping, septate, hyaline. Conidiophores formed as lateral branches of the mycelium, short, branched, septate, hyaline, the branches arising as successive lateral proliferations of the basal cells. Conidia abstricted singly, arising from the terminal cells of the conidiophores in lateral succession in groups, oval to spherical, brown to black.

The species diagnosis is as follows:

Wardomyces anomala n.sp.†

Colonies circular, white to fuscous, adpressed to the substratum, $\frac{1}{8}$–$\frac{1}{4}''$ in diameter.

Hyphae creeping, branched, septate, 2–4 μ wide, hyaline.

Conidiophores short, 15–25 μ long, scarcely differentiated from the vegetative hyphae, branched or unbranched, hyaline.

Conidia abstricted singly, brown to black, smooth, subspherical to oval, usually with slightly pointed ends, 5–8 $\mu \times$ 4–6 μ.

Habitat on flesh of rabbits kept in cold storage.

VI. *PENICILLIUM* spp.

Forms of the common blue-green mould were of frequent occurrence upon cold-store meat, and were occasionally found

* *Wardomyces* gen.nov.

Mycelio repente, septato, hyalino, conidiophoris e mycelio lateraliter exorientibus, brevibus, ramosis, septatis, hyalinis, ramis e cellulis basalibus successive emissis. Conidiis singillatim abstrictis, e cellulis conidiophorarum terminalibus successione laterali gregatim exorientibus, ovalibus vel sphaericis, e brunneo nigrescentibus.

† *Wardomyces anomala* sp.nov.

Coloniis circularibus, e albis fuscescentibus, substrato adpressis, 3–6 mm. diam., hyphis repentibus, ramosis, septatis, 2–4 μ latis, hyalinis. Conidiophoris brevibus, 15–25 μ longis, ab hyphis vegetativis vix differentibus, ramosis vel simplicibus, hyalinis. Conidio singillatim abstrictis, e brunneo nigrescentibus, laevibus, subsphaericis vel ovalibus, plerumque utrinque subacutis, 5–8 $\mu \times$ 4–6 μ.

Hab. Ad cuniculorum carnem in frigidariis asservatam.

upon bacon also. When young, the colonies are white in colour, but when mature they are bluish green. The isolations proved generally to be *P. expansum*, but one has been provisionally identified by Dr Thom of Washington as *P. asperulum* Bainier.

Some evidence has been obtained that certain isolations of *P. expansum* from cold-store meat will germinate and grow at $-6°$ C., but development is very slow and after more than two years the colonies in the culture tubes or on meat are little more than just visible to the naked eye. Growth at this low temperature is sometimes more marked if germination of the spores has proceeded for 24–48 hours before the culture tubes are placed in the cold store. At $-1°$ to $-0{\cdot}5°$ C. growth is more vigorous and at $2°$ C. it is active.

The spores and young mycelial growths also of this fungus are able to withstand exposure to a temperature of $-6°$ C. for long periods. Growth has sometimes taken place or has been resumed after $2\frac{1}{2}$ years at this temperature.

The large colonies of *Penicillium* seen on contaminated meat are in marked contrast to the small growths which have been produced under experimental cold storage conditions, and point to the fact that at some time or other the temperature of the meat has risen to about or just above freezing point. Spores of *Penicillium* are always present in the air, and doubtless are deposited upon the surface of the meat, ready to develop if conditions are suitable for growth. These bluish-green moulds are entirely superficial.

VII. *SACCHAROMYCES* spp.

Both white and pink yeasts were of common occurrence on meat contaminated with mould fungi. These forms develop with great rapidity at temperatures just above freezing point, but there is no evidence yet that they will grow below zero. The fungus described some years ago by Klein (10) as the cause of brown spots on chilled beef should, perhaps, be placed here. Yeast colonies in a dry condition are often brownish in colour, but it is not possible to be certain of the identity of the organism which Klein described. The white and pink yeasts isolated from meat do not form spores, and hence belong to the genus *Torula* used in the sense of Hansen and Jörgensen.

VIII. *THAMNIDIUM* spp.

Species of *Thamnidium* were frequently isolated from meat of various kinds in cold stores, which had become contaminated by mould growths, the type of which known in the meat trade as "whiskers" being usually due to species of this genus. Upon

meat these growths are profuse and are practically indistinguishable from species of *Mucor*. The genus *Thamnidium* differs from *Mucor* in the presence of two different kinds of sporangia, large and small, but in the natural occurrence of *Thamnidium* upon meat the small sporangia are either few or non-existent so that it appears like a *Mucor*. When grown under laboratory conditions, however, both types of sporangia are usually formed; upon nutrient agar small sporangia predominate, but upon cooked meat the reverse is the case. Upon fresh meat in the laboratory large sporangia sometimes occur to the exclusion of small ones.

Two species of *Thamnidium* were frequently isolated from cold-store meat, *T. elegans* and *T. chaetocladioides*, and of these the latter was the more common. It is of interest that these fungi are of rare occurrence upon other substrata, although upon mouldy meat they seem to be particularly common.

At ordinary temperatures and up to 20° C. these species grow well; at 25° C. *T. elegans* grows fairly well but *T. chaetocladioides* develops hardly at all, the spores becoming much swollen and forming curious amoeboid-looking cells. At 30° C. neither species develops.

So far there has been only the slightest signs of growth of either of these species at – 6° C., but at a temperature of 1–2° C. they grow profusely. They also grow at a temperature of – 1° to – 0·5° C.; development at temperatures between this and – 6° C. has not yet been tested. Bidault (2), however, states that *T. chaetocladioides* (= *Chaetostylum Fresenii*) grows at – 10° C.

The spores and even young mycelia will retain their vitality for long periods at a temperature of – 6° C. Thus meat inoculated with spores of *Thamnidium chaetocladioides* in October 1919 and placed in the cold store either immediately or after 24 hours, developed profuse growths of this fungus directly after removal to ordinary temperature in January 1921.

Mould spores of this type, therefore, which may have been deposited on the meat before being placed in store, remain living for long periods at low temperatures, and if there is a breakdown of the refrigerating plant, causing a rise in temperature to about freezing point, it is to be expected that these lurking moulds will develop profusely. Where such "whisker" growths are apparent on the meat, it is probable that the meat has been exposed to a temperature of 0° C. or slightly above for some time during storage. These moulds are entirely superficial and can readily be removed with a cloth. If unaccompanied by putrefactive bacteria, meat affected by these moulds is not dangerous for human consumption.

IX. *MUCOR* spp.

It was practically impossible to distinguish mould growths belonging to this genus from those of *Thamnidium* until the forms were isolated in culture. Together with *Thamnidium*, this genus is responsible for the profuse, greyish-white growths upon cold-store meat known as "whiskers," but species of *Mucor* are less frequently met with in this connection than are *Thamnidium elegans* and *T. chaetocladioides*.

Three species of *Mucor* were isolated from contaminated beef and mutton and these have been kindly identified by Prof. Lendner of Geneva as

M. mucedo Linné,
M. lusitanicus Bonderlein, and
M. racemosus Fres.

M. mucedo and *M. racemosus* are common moulds occurring upon a great variety of substrata.

Like *Thamnidium*, these fungi grow well at 1–2° C., but apart from slight germination of the spores of *M. mucedo* at − 6° C. there has been no indication of growth at this temperature. Tests have not yet been carried out between − 6° and 0° C. At temperatures just above zero, chlamydospores are formed more profusely than at ordinary temperatures.

M. mucedo and *M. lusitanicus* grew well and produced sporangia at all temperatures between 2° C. and 25° C., but did not grow at 30° C. *M. racemosus* grew at 30° C., but no sporangia were formed at that temperature.

The behaviour of these species of *Mucor* on cold-store meat is similar to that of *Thamnidium* and the presence of profuse growths of these forms is probably to be correlated with a rise in temperature to just above freezing point. Like *Thamnidium*, these species of *Mucor* do not penetrate the meat to any extent, nor do they confer poisonous properties upon it.

X. SUMMARY.

(1) The fungi which occur on cold-store meat coming to England from the southern hemisphere have been systematically examined. These moulds are: *Cladosporium herbarum* (the cause of meat "Black Spot"), *Thamnidium chaetocladioides*, *Thamnidium elegans*, *Mucor racemosus*, *Mucor mucedo*, *Mucor lusitanicus*, *Penicillium expansum*, *Penicillium anomalum*, *Saccharomyces* spp. together with two new species, *Sporotrichum carnis* and *Torula botryoides*, and the type species of a new genus, *Wardomyces anomala*.

(2) A general survey of many forms of *Cladosporium* has been undertaken, with the result that many so-called species of *Cladosporium* including *C. epiphyllum* are interpreted as strains

of *C. herbarum* and not distinct species. *Hormodendron cladosporioides* is a spore form of *C. herbarum*, and under cultural conditions is produced at low as well as at high temperatures.

(3) Some strains of *Cladosporium herbarum* will develop from spores at a temperature of − 6° C. and will give rise to considerable growths including conidiophores under prolonged cold-storage conditions. *Torula botryoides*, *Sporotrichum carnis*, *Penicillium expansum* and *Thamnidium* spp. sometimes develop slightly at this temperature, but readily at 0° C., and it is probable that they grow appreciably between these two temperatures; profuse growths of these forms on meat are usually an indication that the temperature has been raised to 0° C. or slightly higher at some time or other during storage. *Mucor* spp., *Saccharomyces* spp., and *Wardomyces anomala* do not develop at − 6° C., but will grow at 0° C. or just above.

(4) Spores and young mycelia of certain of these moulds, notably *Thamnidium* spp. and *Penicillium expansum*, retain their vitality for more than two years at − 6° C., and germinate or continue to develop on removal to ordinary temperatures.

(5) The growth of these moulds on meat is superficial, and even in "Black Spot" the mycelium penetrates only to a maximum depth of 4 mm. These fungi do not confer poisonous properties on the meat, and, unless associated with putrefactive bacteria, do not render the meat unfit for food.

(6) Several of these moulds are of common occurrence on vegetable debris and animal excreta, and their source is substrata of this nature occurring in and around abattoirs in the southern hemisphere. Air-borne spores alight upon the carcases before and during storage, and develop into mould growths at favourable opportunities.

(7) By controlling the temperature and humidity conditions in the cold stores, and by avoiding unduly prolonged storage, the growth of these fungi can be prevented.

XI. REFERENCES.

(1) Bancroft, K.—Researches on the life-history of parasitic fungi. Ann. Bot. xxiv, p. 359 (1910).

(2) Bidault, C.—Sur les moisissures des viandes congelées. Compt. rend. soc. biol. lxxxv (II), p. 1017 (1921).

(3) Brooks, F. T. and Kidd, M. N.—Black spot of chilled and frozen meat. Special report 6, Food Investigation Board, Dept. Sci. and Ind. Research, London, 1921.

(4) Delacroix, G. and Maublanc, A.—Maladies des plantes cultivées. Paris, 1909.

(5) Farlow, W. G.—Vegetable parasites of codfish. Bull. U.S. Fish Commission, vi, p. 1 (1886).

(6) Høye, Kr.—Undersølgelser over Klipfiskesoppen. Bergens Museums Aarsbog, vii, p. 40 (1901).

(7) Janczewski, E. von.—Polymorphisme du *Cladosporium herbarum*. Bull. Acad. Sci. de Cracovie, xxx, p. 417 (1892).

(8) Janczewski, E. von.—Les Périthéces du *Cladosporium herbarum.* Ibid. p. 271 (1893).
(9) —— Récherches sur le *Cladosporium herbarum.* Ibid. p. 147 (1894).
(10) Klein, E.—Report on the nature of brown spots on beef and on the nature of black spots on chilled beef. Quoted in Leighton and Douglas, "The meat industry and meat inspection," pp. 1544, 1553.
(11) Lafar, F.—Handb. d. Technisch. Mykol. iv, p. 270 (1906).
(12) Massee, G.—"Black Spot" of frozen beef. Journ. of Hygiene (1912).
(13) Monvoisin, M.—Les moisissures des viandes congelées. Rec. de Med. Veter. xciv (1918).
(14) Rabenhorst, L.—Kryptogamen-Flora.
(15) Saccardo, P. A.—Sylloge Fungorum.
(16) Schostakowitsch, W.—Über die Bedingungen der Conidienbildung bei Russthaupilzen. Flora, lxxxi, p. 362 (1895).
(17) Tabor, C. J.—Black spot on chilled and frozen meat. Cold Storage and Produce Review, Oct. 20th, 1921.
(18) Talayract, M. J.—Conserves de viandes par les procédés frigorifiques. Ann. d'hygiene publique, sér. 3, xlv, p. 166 (1901).

OBSERVATIONS AND EXPERIMENTS ON CEREAL RUSTS IN THE NEIGHBOURHOOD OF CAMBRIDGE, WITH SPECIAL REFERENCE TO THEIR ANNUAL RECURRENCE*.

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CONTENTS.

* Part of a dissertation submitted for the Ph.D. degree at the University of Cambridge in 1922.

PART I.

INCIDENCE AND MEANS OF OVERWINTERING.

1. INTRODUCTION.

The annual origin of rusts on cereals has been the subject of numerous investigations. In recent years several valuable contributions have been made on different aspects of the problem, attaching special importance to one factor or the other as the cause of infection.

The chief sources of "primary" infection, as has been pointed out, might be (i) uredospores that may survive on the cereals through the critical periods, (ii) an inherited germ of disease within the seed grain, as suggested by Eriksson*, (iii) sori within the seed grain, (iv) aecidiospores on some alternate host, (v) sporidia arising from teleutospores, (vi) uredospores living during the critical period on other grasses.

As far as England is concerned, one finds that no special study of the problem has been made. In literature one comes across only a few general statements based mostly on observation of the fact that the uredo-stage of some rusts can be found every now and then on cereals or wild grasses even during winter and the earlier part of spring—Plowright†, Ward‡ and Grove§. It was desirable therefore that a detailed investigation of the problem should be undertaken at an important wheat growing area in this country.

The work was commenced at the suggestion of Mr F. T. Brooks in October 1920 and carried out for nearly two years at the Cambridge Botany School.

In this part of the paper I propose to give a brief account of the incidence of rusts on wheat in the vicinity of Cambridge and also to discuss the relative importance of the various factors which go to explain the origin of rust outbreaks year after year.

Throughout the period under report, field observations were made as far as possible once a week at the Cambridge University farm and occasionally also at other farms in the vicinity. In addition to the rusts of wheat, observations were regularly made on the black rust of Couch grass (*Agropyron repens*). During the latter half of the period casual observations were also made on the rusts of barley and rye.

Side by side with field work, extensive culture work was

* Carleton, M. A., U.S. Dept. Agric. Div. Veg. Phys. and Path. Bull. No. 16 (1899); Eriksson, J., Compt. Rend. CXXIV, p. 475 (1897).
† Plowright, C. B., Gard. Chron., N.S. XVIII, p. 234 (1882).
‡ Ward, H. M., Ann. Bot., XIX, p. 1 (1905).
§ Grove, W. B., British Rust Fungi (1913).

carried on for a period of nearly two years, with the object of throwing further light on some of the more important physiological differences between the yellow, the brown, and the black rusts of wheat.

2. Review of the Literature.

It is unnecessary to enter into a historical survey of the work done on the cereal rust problem, in view of the fact that it has so often been summarised. In referring to comparatively recent work in different countries, my object is to bring out the various views expressed on the significance of the more important factors that fall within the scope of this paper.

1. Dealing first with the possibility of the uredospores occurring during the critical periods on self-sown plants being the source of infection, one may refer to the observations made by McAlpine* in Australia. In that country *Puccinia graminis* is perpetuated from season to season by means of uredospores. It is important in this connection to note that in Australia it is the heat and drought of summer, and not the winter cold, against which the fungus has to provide.

In some parts of the United States of America, Carleton†, Hitchcock and Carleton‡ and Bolley§ have remarked that fresh uredospores of *Puccinia Rubigovera* are found throughout winter. In a later contribution Bolley|| has stated that the uredospores of *P. graminis* also can withstand the cold of a North Dakota winter. Carleton†, however has denied the possibility of the black rust (*P. graminis*) of wheat being able to overwinter in Kansas. Again Pritchard¶ has pointed out that the uredospores of *P. graminis* when kept in the open lost their viability in two months' time. The same author also remarked that in North Dakota the wintering of *P. graminis* as mycelium in plant tissues is very doubtful.

Hoerner** has made a similar observation about the brown rust of oats.

Jaczewski†† has stated that black rust in Russia cannot overwinter and that even the mycelium of this rust inside the host cannot withstand frost.

* McAlpine, D., The Rusts of Australia (1906).

† Carleton, M. A., U.S. Dept. Agric. Div. Veg. Phys. and Path. Bull. No. 16 (1899).

‡ Hitchcock, A. S. and Carleton, M. A., Kansas Agric. Coll. Exp. Stat., Bull. 46 (1894).

§ Bolley, H. L., Centralbl. f. Bakt. IV, Abt. 2, p. 893 (1898).

|| Bolley, H. L., Science, XXII, p. 50 (1905).

¶ Pritchard, F. J., Bot. Gaz. LII, p. 169 (1911).

** Hoerner, G. R., Amer. Journ. Bot. VIII, p. 452 (1921).

†† Jaczewski, A., Zeitschrift für Pflanzenkrankheiten, XX, p. 321 (1910).

Klebahn* has remarked that in Germany *P. dispersa* and *P. glumarum* can overwinter in the uredo-stage, but *P. graminis* cannot do so.

On the other hand Eriksson and Henning† state that in Sweden none of the three rusts under report can overwinter in the uredo-stage.

In India Butler‡ has stated that self-sown plants are very rare and probably quite absent in the hotter parts of that country, where, like Australia, the period most critical for rusts is the intensely hot summer. He has further remarked that attempts to preserve uredospores in the earlier part of the hot weather have been unsuccessful.

From a cursory perusal of the observations quoted above it is clear that on account of great climatic differences between the countries referred to, the incidence of rusts could not possibly have been similar. Apart from its incidence one has to enquire whether a certain rust can or cannot pass the unfavourable period inside the host in the mycelial stage. Again it is doubtful if the small number of uredospores that may have survived through the critical period would be enough to bring about a "spontaneous outbreak" of a certain rust. This question becomes still more difficult to answer in view of the fact, which will be proved later, that in a cold country rusts take a much longer time to develop pustules even during spring than has hitherto been believed.

2. Eriksson§, as is well known, has attributed the fresh outbreak of rusts to an internal, inherited and invisible germ of disease inside the seed grain which he considers may take from two weeks to nine months from the time of sowing to assume a visible form, but there are few believers in this "mycoplasm hypothesis" at the present day.

Bolley|| has stated in contradiction to Eriksson's view that there is much evidence that all infection of new grain plants comes from without, and that there is nothing to prove an internal symbiotic life. Similarly the negative results obtained by Marshall Ward¶ in his pure culture experiments with seeds from rusted grasses, and those conducted by Butler and Hayman** at Cawnpore, prove conclusively that no rust develops from the "mycoplasm" suspected of being inside the seed grain.

* Klebahn, H., Die Wirtswechselnden Rostpilze (1904).

† Eriksson, J. and Henning, E., Die Getreideroste (1896).

‡ Butler, E. J., Fungi and Disease in Plants (1918).

§ Eriksson, J., Compt. Rend. CXXIV, p. 475 (1897); Ann. Bot. XIX, p. 55 (1905).

|| Bolley, H. L., Proc. Amer. Assoc. Adv. Science, XLVII, p. 408 (1898).

¶ Ward, H. M., Ann. Bot. XIX, p. 1 (1905); Proc. Roy. Soc. LXIX, p. 451 (1902).

** Butler, E. J. and Hayman, J. M., Mem. Dept. Agric. India, Bot. Ser. I, No. 2 (1906).

Again Bailey* has quite recently denied the possibility of a "primary" outbreak of the Hollyhock rust from internal infection.

In the absence of a positive proof of the origin of rust on seedlings grown under conditions that would forbid all external infection, we cannot but conclude that, although Eriksson's researches on cereal rusts have been exceedingly useful, his suggestion about their propagation through "mycoplasmic symbiosis" does not carry us any nearer to the solution of the problem of their recurrence.

3. With reference to the view that infection is carried from year to year by means of infected seed, it is interesting to note that Pritchard† has sketched definite figures of the mycelium of *P. graminis* inside seedlings from grain that had teleuto-sori facing the embryo. He has however not been able to record the appearance of any pustules on such plants. Beauverie‡ also believes in the transmission of rust through infected seed. Recently Hungerford§, on the strength of elaborate experiments, has strongly denied the possibility of the propagation of rust from one crop to the next by means of rusted seed grain, and so has Eriksson||.

4. While discussing the importance of intermediate hosts, one has to bear in mind the fact that as far as yellow rust is concerned, no such host has yet been discovered. As regards the brown rust of wheat (*P. triticina*), only recently Jackson and Mains¶ have been able to achieve successful infection of species of *Thalictrum* with its sporidia.

In the case of black rust too McAlpine** states that in Australia the barberry plays no part as an intermediate host, the rust being perpetuated from season to season by uredospores. Henning†† has also expressed the same view about warm countries in general where the barberry does not exist.

Butler‡‡ has stated that aecidiospores found on barberry in some of the hills could not infect wheat; and has concluded therefore that the aecidial stage is of no account in India.

Pritchard§§ has remarked that the absence of barberry, or its

* Bailey, M. A., Ann. Bot. XXXIV, p. 173 (1920).
† Pritchard, F. J., Phytopathology, I, p. 150 (1911).
‡ Beauverie, J., Rev. Gén. Bot. XXV *bis*, p. 11 (1914).
§ Hungerford, C. W., Journ. Agr. Res. XIX, p. 257 (1920).
|| Eriksson, J., Phytopathology, XI, p. 385 (1921).
¶ Jackson, H. S. and Mains, E. B., Phytopathology, XI, Abstracts, p. 40 (1921).
** McAlpine, D., The Rusts of Australia (1906).
†† Henning, E., Tidsk. f. Landtmän, XXVIII, 1917. Abstract in Hedwigia, LXI, p. (49) (1919).
‡‡ Butler, E. J., Fungi and Disease in Plants (1918).
§§ Pritchard, F. J., Bot. Gaz. LII, p. 169 (1911).

existence at very distant places, makes spring infection of wheat inexplicable, and has suggested the possibility of infection of wheat due to teleutospores being of greater importance.

Lastly Eriksson* inclines also to the view that propagation to and from the aecidial host is very slight.

On the other hand one learns from the contributions of Plowright†, Stakman and Piemeisel‡, Freeman and Johnson§, Lind||, Güssow¶, Broadbent** and others that there is a definite connection between the aecidium on barberry and the distribution of black rust on graminaceous hosts. To avoid repetition, this factor and the next two will be discussed in detail later in the text.

The present work was taken up chiefly with the object of finding out (i) if one could satisfactorily explain the fresh attacks of different rusts on wheat in spring, taking the uredospores surviving on self-sown plants during winter as the source of infection; (ii) whether the amount of such uredospores could, with a reasonable amount of certainty, be held responsible for the more or less spontaneous outbreak of rusts over large areas of winter wheat; (iii) if one could find the cause of the more or less fixed sequence in the appearance of the three rusts; and also (iv) the relative importance of some of the other factors already referred to.

3. Black Rust (*Puccinia graminis* Pers.).

(*a*) *Incidence.*

This rust does not appear on graminaceous hosts until late in the season. In the year 1921 it was first noticed towards the end of June on Couch grass (*Agropyron repens*). In the vicinity of Cambridge it is not common, and it has not been found on any other local wild grass. Amongst the cereals it was observed on wheat alone in the year 1920 and only on barley last year (1921).

(1920–21.) There was plenty of the uredo-stage on wheat (self-sown) and Couch grass in October but later on no fresh uredo-sori were observed. In January 1921 one could find only old and disfigured uredo-sori. No black rust was observed at

* Eriksson, J., Bot. Gaz. XXV, p. 26 (1898).

† Plowright, C. B., Gard. Chron., N.S. XVIII, p. 234 (1882).

‡ Stakman, E. C. and Piemeisel, F. J., Journ. Agr. Res. X, p. 429 (1917).

§ Freeman, E. M. and Johnson, E. C., U.S. Dept. Agr. Bur. Plant. Indus. Bull, p. 216 (1911).

|| Lind, J., Danish Fungi as represented in the herbarium of E. Rostrup (1913).

¶ Güssow, H. T., Phytopathology, III, p. 178 (1913).

** Broadbent, W. H., Journ. Minis. Agric. XXVIII, p. 117 (1921).

the University farm on self-sown plants or regular crops in the spring or summer of 1921.

(1921–22.) No black rust was found on cereals or wild grasses at the University farm in the autumn of 1921 or the spring or summer of 1922, even up to harvest time.

It may be pointed out that the greater portion of the plot under observation in the autumn of 1920 was left unploughed and one could see a large amount of old straw with teleutosori throughout the spring and summer of 1921. The new crop of wheat was sown on the adjacent plot.

This total absence of black rust goes a long way to disprove the possibility of direct infection of graminaceous hosts by sporidia produced on the germination of teleutospores which were present in plenty on the adjacent plot.

It is essential in this connection to state that there are no plants of wild barberry known to exist in the near neighbourhood of the University farm.

(*b*) *Overwintering of the uredospores.*

It is very doubtful if fresh pustules of black rust are at all developed during the winter months in this locality. During the last two winters (1920–21, 1921–22), although comparatively mild, no such pustules were observed. Moreover the complete absence of this rust on self-sown plants of wheat which bore uredo-pustules of both yellow and brown rusts during the greater part of the cold season (1920–21) indicates that black rust cannot stand the cold of an English winter. Similarly Couch grass (perennial as it is), which was once covered with this rust in the autumn of 1920, has never shown a pustule of it at the University farm since that time.

Plants of rusted Couch grass transplanted to pots in November and kept in the open showed no uredo-sori after two months and have since then been quite free from them.

As regards the viability of the uredospores collected from the open in winter, it may be pointed out that inoculations tried on wheat in the laboratory during November and early in December 1920 gave satisfactory results and the spores showed good germination. By the second week of December the spores had practically lost their viability, and consequently it was impossible to infect seedlings even in the laboratory with uredospores (old as they were) from the open after that date.

That the loss of viability was due to the effect of cold is clear from the fact that since November 1920 up to July 1922 the writer successfully kept a culture of this rust in the laboratory.

(c) *Hibernation through sori in seed.*

Reference has already been made to the experiments conducted by Hungerford* with rusted grain of wheat. In the summer of 1921 while carrying on some work on the specialization of black rust, some seedlings of Couch grass were raised from healthy as well as from badly rusted grain collected in the autumn of 1920. It was found that rusted grain invariably gave healthy plants, and there was no trace of rust even on plants as many as ten weeks old. Only those seedlings which were artificially inoculated developed the disease, and the controls never became rusted. The writer is in complete agreement with the view expressed by Hungerford, that propagation of rust through infected seed is improbable.

(d) *Aecidium on barberry and fresh outbreaks of rust.*

Recently Stakman and Piemeisel† have stated that they are in doubt as to the importance of the overwintering of the uredo-stage on grasses, but have remarked that barberry may be important at least locally.

Similarly Freeman and Johnson‡ have observed that aecidiospores may be sufficient in number (in spite of their short viability) to cause epidemics on grasses.

Broadbent§ has pointed out that there is a plentiful distribution of the common barberry in the counties of Carmarthenshire, Cardiganshire and Pembrokeshire, and that black rust on wheat is generally distributed over the same area. In all other parts of the British Isles he states that black rust is scarce.

Lastly Lind‖ and Güssow¶ have made an important statement that the gradual extermination of barberry since 1903 has brought about a great decrease in the severity of black rust in Denmark.

The complete absence of black rust in the summer of 1921 at the University farm has been noted above but it was found on Couch grass and barley at a farm near Cambridge in the same season. This farm was known to have a few plants of barberry in the hedgerow which were kept under observation from the beginning of spring. Ripe aecidia were noticed on the barberry on the 6th of June and till then there was no trace of black rust although the standing crop of barley had plenty of *P. simplex*

* Hungerford, C. W., Journ. Agr. Res. XIX, p. 257 (1920).

† Stakman, E. C. and Piemeisel, F. J., Journ. Agr. Res. X, p. 429 (1917).

‡ Freeman, E. M. and Johnson, E. C., U.S. Dept. Agr. Bur. Plant. Indus. Bull. p. 216 (1911).

§ Broadbent, W. H., Journ. Minis. Agric. XXVIII, p. 117 (1921).

‖ Lind, J., Danish Fungi as represented in the herbarium of E. Rostrup (1913).

¶ Güssow, H. T., Phytopathology, III, p. 178 (1913).

and also yellow rust here and there. On the 24th of June for the first time in the season Couch grass just below infected bushes of barberry was seen covered with uredo-sori of black rust. By the middle of August the disease had spread to barley as well. The attack was a mild one and rusted plants were observed only within ten to fifteen yards of the hedgerow. By the third week of October the uredo-stage became very rare and during winter and the following spring (1922) no uredo-stage could be found.

Towards the end of May ripe aecidia on barberry were again noticed at the same farm. A fortnight later the uredo-stage was quite common on Couch grass just below the infected bushes of barberry. By the end of July the rust had spread on Couch grass over a considerable area, the weather being very favourable.

One could safely attribute the exceedingly restricted and mild nature of the attack of black rust as recorded above and its complete absence at the University farm, last year (1921), to the exceptionally dry and warm weather during the latter part of spring and the whole of summer. Undoubtedly the weather conditions were most unfavourable, both for an extensive infection by the aecidiospores and also for the spread of this rust by the uredospores. This probably explains why black rust was conspicuous by its absence last summer at the University farm. It may be pointed out that last summer wheat and barley were simply covered with yellow and brown rusts which it must be remembered had already established themselves during the earlier part of the year.

(c) *Inoculation experiments with sporidia.*

Eriksson and Henning* while denying the possibility of the survival of uredospores through the winter have attached special importance to the view that teleutospores may on germination cause direct infection of graminaceous hosts by their sporidia.

In the spring of 1921 some inoculation experiments were conducted on young seedlings of wheat to see if they could be infected with sporidia of *P. graminis tritici*.

From the 22nd of February up to the 6th of April several germination tests were made with teleutospores that had been kept in the open throughout winter, and they invariably showed good germination. On the 6th of April two plants of barberry (as control) and many young seedlings (six days after sowing) of wheat were inoculated with teleutospores mixed in water. On the fourteenth day inoculated leaves of barberry showed spermogonial patches. Seedlings of wheat showed only brownish

* Eriksson, J. and Henning, E., Die Getreideroste (1896).

streaks on the stem. These streaks were fixed and microtomed but no mycelium could be discovered. No pustules of rust were noted on wheat even up to the 20th of May (nearly six weeks after inoculation).

These negative results prove that sporidia cannot infect the graminaceous host directly.

(*f*) *Inoculations with aecidiospores.*

That the latter part of spring (1921) was unfavourable for an extensive infection of cereals by aecidiospores from barberry in this locality will be clear from the following observations.

During the months of June and July as many as six attempts were made to inoculate seedlings of wheat and Couch grass with aecidiospores from barberry in the open, or with such material as had been cultivated in the laboratory. All the inoculations were made in a cool green-house.

Excepting once, the aecidiospores from the open showed poor germination and out of thirty-six seedlings of Couch grass only three took infection. In the case of wheat (Red Sudan) out of forty-one seedlings only seven developed uredo-sori. The pustules on wheat it must be pointed out were exceedingly small (very much smaller than those on Couch grass). This form was later on found to be *P. graminis secalis*.

In summing up one may state that as far as the neighbourhood of Cambridge is concerned, and the same is probably true of other parts of England, the appearance of black rust year after year starts with the fresh infection of cereals by the aecidiospores from barberry. Also that there is no possibility of the perpetuation of this rust through overwintering uredospores, even after comparatively mild winters, like the two under report.

The question of the possibility of the survival during winter by means of the mycelium inside the tissues of the host plant, will be discussed later on.

4. The Brown Rust (*P. triticina* Erikss.).

(*a*) *Incidence.*

A study of the incidence of this rust, and its culture in the laboratory is interesting, as it combines the power of resistance to cold, so characteristic of yellow rust, with the capacity to withstand warmer weather, as exhibited by black rust. The rust is quite abundant in the neighbourhood of Cambridge and, as Grove* has mentioned, in England as a whole. It appears on

* Grove, W. B., British Rust Fungi (1913).

wheat early in spring usually a little later than the yellow but long before the black rust. Butler* has stated that in India it is the earliest to appear on wheat. The uredo-sori of this rust in summer resemble those of black rust on leaves and are often mistaken for them.

Ward†, Carleton‡, Hitchcock and Carleton§, Bolley|| and others to whom reference has already been made have pointed out that the uredospores of brown rust can be found during winter. The following is a brief summary of the observations made by the writer.

(1920–21.) There was plenty of the uredo-stage of the rust on self-sown wheat in October and November but after a heavy frost in December it was very rare for a period of two months though not altogether absent. By the third week of February it again became quite common on self-sown wheat. For the rest of the season up to the harvest time the rust was plentiful on the wheat crops. Barley was observed to be heavily infected by *P. simplex* and the brown rust of rye too was very common.

(1921–22.) After the harvest of 1921 it was observed here and there round Cambridge and the brown rusts of barley and rye were also noted on self-sown plants. During autumn and the whole of winter the rust was not difficult to find on wheat except for a short time in January 1922 when it was rather rare. *P. simplex* was also noted on barley occasionally. By the middle of March it had established itself on the crop and was very common in summer (1922) up to the harvest time.

In addition to the above may be quoted some interesting observations, made on a small plot of Luther Burbank wheat (a very susceptible variety) sown at the Botanic garden on August 10th, 1921. This plot was kept under frequent observation. Throughout the season (1921–22) brown rust was found on this plot. Fresh uredo-sori were, however, rather rare in the latter half of January after frost. It is of interest to note that this plot showed no yellow rust for a period of over ten months.

As far as this rust is concerned, it may safely be stated that for the period the data cover it is transmitted from season to season by uredospores.

We cannot, however, take the last two winters as anything

* Butler, E. J., Fungi and Disease in Plants (1918).

† Ward, H. M., Ann. Bot. XIX, p. 1 (1905).

‡ Carleton, M. A., U.S. Dept. Agric. Div. Veg. Phys. and Path. Bull. No. 16 1899).

§ Hitchcock, A. S. and Carleton, M. A., Kansas Agric. Coll. Exp. Stat., Bull. 46 (1894).

|| Bolley, H. L., Centralbl. f. Bakt. IV, Abt. 2, p. 893 (1898).

like a severe test; moreover after a frost or during a cold spell this rust too was very rare though not altogether absent. For these reasons it is doubtful, if one could safely attribute the outbreaks on the autumn-sown crop early in spring to the few uredospores that may be lurking in the open. This rust may be altogether absent during the greater part of a severe winter. Eriksson and Henning* have observed such a condition in Sweden.

At the same time one cannot conclude, from the absence of uredo-sori even for the whole period during a severe winter, that uredospores from the last season's crop have no significance as a source of infection to the autumn-sown (new) crops. The real source of danger is the abundance of uredospores on self-sown plants at autumn time and they will have done their work before the winter sets in.

(*b*) *Overwintering of the uredospores.*

As regards the viability of the uredospores of this rust taken from the open during winter, the writer agrees with Plowright † who found that spores which had been exposed to several nights of frost germinated with the greatest freedom. Further it may be added that during the last two seasons several inoculations on wheat were made in the open during winter with fresh uredospores of this rust resulting in satisfactory infections of the host.

(*c*) *Aecidium on* Thalictrum.

It is difficult to say anything definite on the possible infection of wheat by the aecidiospores found on species of *Thalictrum*. The aecidial stage on *T. flavum* in this country has been connected with *P. persistens* on *Agropyron repens*. It is interesting, however, to note that the brown rust of wheat was observed in plenty in the latter half of February (1921) and this year it was noted on the wheat crop in the middle of March, whereas the aecidium on *T. flavum* occurs from May to July (Grove‡). Even if the aecidium on *Thalictrum* proves to be connected with *P. triticina*, it is unlikely to have anything to do with the fresh origin of that rust each year.

* Eriksson, J. and Henning, E., Die Getreideroste (1896).
† Plowright, C. B., Gard. Chron., N.S. XVIII, p. 234 (1882).
‡ Grove, W. B., British Rust Fungi (1913).

5. The yellow rust (*Puccinia glumarum* Erikss. and Henn.).

(*a*) *Incidence.*

This rust is usually the earliest to appear and was noticed in the year 1921 as early as the third week of January on winter wheat at the University farm. It can be easily distinguished from either of the other two rusts by the orange-yellow colour of its uredo-sori, which are always arranged in long rows.

As regards its incidence, there is absolutely no similarity between the data recorded for the two seasons under report as the following account will show.

(1920–21.) The uredo-stage was very common in October on self-sown wheat on a small plot just outside the cages at the University farm. The plot was ploughed early in November but there was plenty of the rust on self-sown plants on some of the beds inside the cages also. During December and the earlier part of January 1921 it was very rare and was found only as old pustules on withered leaves. On the 20th of January strips of fresh pustules were noted on several leaves of the winter wheat crop in cages sown in October 5–7th 1920. Since then the rust was seen spreading rapidly and took an epidemic form by the middle of March. Towards the latter half of July when the weather was exceedingly warm fresh pustules were rather rare. The harvest was reaped by the end of July.

(1921–22.) In the month of August the rust was very rare on self-sown wheat or barley. During September and October too it was practically absent and no trace was found of it round Cambridge (in spite of a very thorough and daily search) except four or five self-sown plants on the 25th of October. It may be pointed out that during this period the brown rusts of wheat and rye (*P. dispersa*) and the dwarf rust of barley (*P. simplex*) were fairly common. From the 25th of October up to the end of May (1922), a period of over seven months, no trace of this rust was seen in this locality. It was first noticed in the beginning of June, but in spite of very favourable weather up to the harvest time the attack was an exceptionally mild one.

(*b*) *Discussion of "Mycoplasm hypothesis."*

At this stage the writer may refer to other observations which were made on some of the most susceptible varieties of wheat and barley sown in the open last autumn (1921).

1. Seedlings of Red Sudan wheat raised in the laboratory were transplanted in a small plot outside the cages on August 24th. Some of the seedlings were transplanted to a bed outside the laboratory.

2. Seedlings of a Mesopotamian variety of barley, exceedingly susceptible to yellow rust, were transplanted outside the cages and also outside the laboratory.

3. Several self-sown plants of barley and wheat were transplanted on October 17th from the cages to the beds outside. There was plenty of mildew, but no rust on these plants.

All three sets of plants were frequently examined for the appearance of yellow rust under conditions most unfavourable for an infection from without, because of the almost complete absence, as far as could be seen, of yellow rust around Cambridge.

Up to the end of May 1922 no trace of yellow rust was observed on any of these plants. Occasionally a few pustules of *P. triticina* on wheat and *P. simplex* on barley were noticed on plants transplanted outside the cages. Brown rusts both on barley and wheat, as has already been pointed out, were present on self-sown plants from the previous harvest (1921). Again, as remarked above, while dealing with the incidence of brown rust, Luther Burbank wheat growing at the Botanic garden all along (Sept. 1921 to July 1922) showed uredo-sori of that rust, but not even once was yellow rust noticed on that plot up to the end of June 1922 (a period of over ten months).

It is difficult to understand why yellow rust should not have appeared on the winter crops, on the wheat at the Botanic garden, and even on plants of varieties known to be exceedingly susceptible, if there was anything like an internal germ of disease in existence. It is essential in this connection to point out that the variety of Mesopotamian barley referred to above was very badly smitten with yellow rust during the summer of 1921.

Plants of Red Sudan wheat and barley had been exposed in the open at the University farm for more than ten months, without showing a pustule of yellow rust.

To make this point still more forcible, it may be mentioned that wheat artificially inoculated with yellow rust on Oct. 26th, 1921, bore pustules in less than three weeks' time, so there could be little doubt about the weather being favourable for the internal germ of disease to manifest itself if it did exist.

Again wheat inoculated with the same rust early in March and kept in the open developed pustules in a fortnight.

The fact that brown rust was flourishing during the greater part of this period, and was never altogether absent, shows that climatic conditions were not unfavourable. Keeping the data of the incidence of this rust for the season 1920–21 and 1921–22 in mind, one cannot help suspecting, that there is a clear connection between the incidence about autumn time and the origin of rust on winter crops in the following spring, as the following chart will show.

Date	1920–21	1921–22
October	Common	Only 4 to 5 plants
November	Very common	Oct. 25th. None afterwards
December	Rare	No trace
January 21st	On fresh crop	,, ,,
February	Very common	,, ,,
March	Epidemic	,, ,,
April	,,	,, ,,
May	,,	,, ,,
June	,,	Just appearing

It has been shown that climatic conditions during winter and spring (1921–22) could not be taken as a factor in accounting for the absence of yellow rust this year. Evidently one is forced to the conclusion that the source of infection for the winter crop lies in the uredospores occurring on self-sown plants about autumn time.

Again it has been stated above that wheat sown late in the season (Nov. 30th, 1920) did not get rusted till March 3rd, some six weeks later than the crop sown Oct. 5–7th. It may be pointed out that by the time the seedlings could appear uredospores were very rare so that the chances of an infection at that time were scanty. Besides, from the 12th of December 1920 onwards, there was an exceptionally heavy frost which lasted more than a week. Early in January 1921 again the uredo-stage was very rare. Keeping these facts in mind one can safely conclude that most probably the infection of the wheat plot under discussion was due to wind-blown uredospores, as there was plenty of yellow rust available by the end of January. The reason why this plot did not show any rust till the beginning of March will be clear from a study of facts discussed under "incubation periods."

As regards the seedlings transplanted outside the laboratory it is interesting to note that up to the middle of July (when the plants were quite ripe and dry) no trace of yellow rust was found on these plants, in all for a period of over eleven months.

For the reasons given above the writer has come to the conclusion that the unprecedented late appearance of yellow rust in the year 1922 in the locality under report was due to the absence of a local source of infection during the autumn and winter of 1921–22. Further, that the source of infection for the rust which was noticed in June was in all probability wind-blown uredospores coming from a place* distinctly cooler or such where the uredo-stage (perhaps under protection) had escaped injury in the summer of 1921. The fact that weather conditions in the summer of 1921 (exceptionally hot as it was) were most unfavourable for the infection of aftermath and self-sown plants by yellow rust will be discussed later.

While summing up it may be remarked that negative results from the cultures of exceedingly susceptible varieties, even when exposed in the open, under conditions of weather undoubtedly favourable for the growth of the fungus go a step further to prove that there is no hereditary source of infection.

(*c*) *Overwintering of uredospores.*

As regards the viability of the uredospores of this rust it may be stated that inoculations conducted with material from the open several times during the winter and spring of 1920–21 gave satisfactory results and the spores invariably showed good germination.

6. Influence of Temperature on the Viability of Uredospores.

Marshall Ward† found that the minimum temperature at which the uredospores of *P. dispersa* on Bromes germinate lies between 10–12° C., the optimum being at or near 20° C., and the maximum between 26–27·5° C. Johnson‡ has stated that the uredospores of *P. graminis* and *P. Rubigovera* can germinate between 2–31° C., the optimum lying between 12 and 17° C.

As far as *P. graminis* is concerned the writer has found that it shows better germination at 29–30° C. than at 2–3° C. At 22–23° C. germination of more than 80 % spores of this rust has frequently been observed. The uredospores of *P. triticina* on the other hand show better germination at 2–3° C. than at 29–30° C.; at 22–23° C. it does not show more than 50 % germination. Lastly *P. glumarum* shows 20–30 % germination

* Early in the year 1922 yellow rust of wheat (though rare) was available in some parts of England. The writer obtained some material from Harpenden in January.

† Ward, H. M., Ann. Bot. xv, p. 560 (1901).

‡ Johnson, E. C., Phytopathology, II, Reviews (1912).

at 2–3° C., not more than 5 % at 22–23° C. and no germination at all at 29–30° C.

On the strength of some further trials the writer has come to the conclusion that the uredospores of *P. glumarum* germinate better than either of the other two rusts at 2–3° C. At 22–23° C. (near the upper limit) those of *P. graminis* germinate better than *P. triticina* but those of *P. glumarum* show very poor germination.

Above 5° C. and up to 20° C. all the three rusts germinate well.

It has been pointed out above that black rust cannot withstand cold, whereas both yellow and brown rusts resist it well. This fact is further borne out by the results of a large number of experiments conducted at different times of the year with uredospores of almost the same age after exposing them to low temperatures in cold storage. The material used in these experiments was cultivated in the laboratory. In all the experiments the controls were kept at laboratory temperatures at which the germination tests were made. The following is a brief summary of the results:

A. Black rust (*P. graminis*).

After exposure to – 6·5 to – 10° C. for 24 hours the uredospores of this rust do not show even 10 % germination and after four to seven days there is a total loss (only one or two spores germinating) of viability.

When exposed to 2·5° C. the spores retain nearly 10 % viability even after one month. They show as much as 50 % germination after exposure to 5° C. for a month.

B. Brown rust (*P. triticina*).

The uredospores of this rust on the other hand show as much as 50–60 % germination after exposure to – 6·5 to – 10° C. for twenty-four hours and even after a week retain nearly 30 % of their viability. After one month's exposure their viability falls to 15 %.

At 2·5° C. and 5° C. the uredospores retain as much as 25 % of their viability after a month's exposure.

C. Yellow rust (*P. glumarum*).

After exposure to – 6·5 to – 10° C. for twenty-four hours the uredospores of this rust germinate quite as well as those of brown rust. After four days they show nearly 25 % germination, but by the end of a week only 10 % spores are viable. At 2·5° C. and 5° C. they retain 15–20 % of their viability after an exposure for one month.

It is essential to point out that the above results are not absolutely constant and that casual variations in the per-

centage of germination may be observed on account of the age of the spores and possibly also on account of the different weather conditions to which the material might be exposed before its removal from the host.

From a comparison of the above results with those obtained from the controls kept at laboratory temperatures the writer has come to the conclusion that in the case of yellow rust there is a rapid fall in the germination capacity of the uredospores. When kept in the laboratory their viability fell down from 80 % to 25 % after a week and by the end of a month the spores showed only 5 % germination, whereas the same rust as already stated keeps nearly 20 % of its viability at 2·5° C. or 5° C. for a month.

The uredospores of black rust, however, show the least amount of impairing in their viability at laboratory temperatures because even after a month they showed as much as 50 % germination.

Brown rust seems to suffer more than the black but much less than the yellow one retaining nearly 30 % of its viability for a period of one month at laboratory temperatures. To elucidate this fact still further two more tests were made in April 1922 for which a constant record of temperature was kept with a thermograph.

Uredospores of all the three rusts were taken fresh from plants inoculated on the same day and kept in the same greenhouse throughout. The temperature of the greenhouse was kept well within favourable limits (4·5–21° C.) and only once or twice rose for a few minutes to 26° C.

1. Spores about ten days old gave the following results when tested at 10·5–15·5° C. (Average for twenty-four hours 12·8° C.)

P. glumarum:	nearly 50 %	germination
P. triticina:	about 60 %	,,
P. graminis:	nearly 75 %	,,

2. Spores nearly five weeks old gave the following results at the same temperatures as above and germinated at the same time.

P. glumarum:	below 10 %	germination
P. triticina:	about 30 %	,,
P. graminis:	nearly 70 %	,,

These experiments show clearly that uredospores of black rust keep better at ordinary temperatures than either of the other two rusts and that those of yellow rust suffer the greatest loss of viability. By comparing these results with those already quoted one can easily see that it is not only temperature that is responsible for the loss of viability so obvious in the case

of yellow rust, but that the uredospores are on the whole very short lived. It has been shown that even at 5° C. (by no means a high temperature) after one month's time they retain only 20 % of their viability. Besides one finds that a considerable number of spores, even when removed from pustules hardly a week old, look quite dark under the microscope and show a complete absence of the characteristic orange coloured contents. Such spores do not germinate at all. Undoubtedly the uredospores of this rust keep better at lower temperatures.

The uredospores of brown rust are longer lived than those of the yellow one and also keep better than them at warmer temperatures.

It may be pointed out in this connection that considerable difficulty was encountered in keeping the culture of yellow rust in the summer of 1921, as it was abnormally warm. On account of the frequent failure of infection the pure culture that had been kept going since Nov. 1920 was lost. Moreover all attempts to establish a new one were unsuccessful. There was occasionally a little infection after a prolonged incubation but it seldom gave enough material for re-infection. The impaired condition of the uredospores and their subsequent failure to infect the host even when protected from direct sunlight suggests that conditions for the fresh infection of wheat and other cereals were very unfavourable in the summer of 1921. On account of the exceptionally high temperature (the average maximum in the shade during July was as much as 26·2° C.) it is probable that the uredospores suffered great injury. It is no wonder therefore that the rust was practically absent during the autumn and winter of 1921–22, whereas brown rust was noted on wheat and rye throughout that period. The occurrence of *P. simplex* on barley and of black rust on Couch in the autumn of 1921 has already been recorded.

It is interesting to note that with additional precautions it was possible to keep the cultures of both brown and black rusts going even during the summer of 1921.

7. Incubation Periods.

As remarked above Eriksson* has allowed a very variable time limit for the "mycoplasm" to assume a visible form. While writing about one definite season he states, "the period lacking mycelium in the wheat plant's life must be short, e.g. two to three weeks in October after sprouting," because he found fresh pustules of yellow rust in November. In another season he says that this period extended over nearly nine months.

* Eriksson, J., Ann. Bot. XIX, p. 55 (1905).

He also states as the chief argument in favour of his hypothesis, that normally the fresh outbreak of rust takes four to six weeks after sowing, and denies, on the strength of this observation, that the source of infection could ever be the uredospores present at the time of sprouting.

This interpretation of Eriksson is based on the opinion that the rust does not take more than eight to ten days from the time of infection to produce pustules.

All the above phenomena, curious as they seem, are easily explicable in the light of the fact that the incubation period is not only not fixed at eight to ten days, but is most variable, and that temperature more than anything else is the regulating factor.

While dealing with incidence it was stated that in October and a part of November 1920 there were a large number of self-sown plants of wheat practically covered with yellow rust growing just outside the cages, where winter wheat was sown in the first week of October. In the beginning of January 1921 the rust was exceedingly rare and was found only as old pustules on a few withered leaves.

On the 20th of January 1921 (about fourteen weeks after sowing) yellow rust was observed on the wheat crop inside the cages. On account of the exceedingly short distance (less than ten yards from some beds) between the rusted plants and the new crop, there could be very little doubt about the source of infection for the young seedlings.

On the 3rd of February last year, some inoculations were tried on wheat seedlings, with material from the rusted plants in the cages, primarily to see if infection does take place in the open during the cold weather and if so how long the pustules take to appear. As a control inoculations were tried in the laboratory and the pot removed to a greenhouse at 60–70° F. The inoculated spots were clearly marked.

1. Pot No. 1. Seedlings inoculated in the open and kept in the open throughout. Pustules on the 36th day.

2. Pot No. 2. Control. Pustules on the 13th day.

Minimum temp. on the 3rd and 4th	23–25° F.	} in screen.
Maximum ,, ,, ,,	43·8° F.	

Unfortunately the germination tests were not very reliable as most of the spores sank to the bottom of the watch glasses.

The experiment was therefore repeated a week later and the results were as follows:

Pot No. 1. In a heated greenhouse throughout.
Pustules on the 13th day.

Pot No. 2. In a cool greenhouse throughout (45–60° F.).
Pustules on the 28th day.

Pot No. 3. In the open throughout—spores 60–70 % germination.
Pustules on the 34th day.

On the strength of these results one can easily explain why in a colder part of the year the rust took nearly ten to eleven weeks from the probable time of its having gained entry into the young seedlings, to develop pustules. The lowest temperature in the shade for February 1921 was 23° F., the highest was 61° F., the average minimum was 33·3° F. and average maximum 47·6° F.

Hecke* in Austria has shown clearly that the upper limit of the incubation period in the case of yellow rust may go up to five months in a winter which was much more severe than the one we had, except for one week in the middle of December in the year 1920–21. He inoculated wheat on October 28th, which, exposed to winter cold, did not develop pustules till March 28th.

Undoubtedly a very severe winter with more frequent frosts may prolong this period by a few weeks, and if the earlier part of spring also happens to be cold, pustules may not appear till summer actually begins.

It would be useless to enter into the details of all the experiments conducted on the length of the incubation period of this rust under different conditions so only the results of a few conducted in the open will therefore be given.

1.	Wheat inoculated	Feb. 23rd, 1921	Pustules on the 25th day.
2.	,, ,,	March 24th, 1921	,, ,, 14th ,,
3.	,, ,,	Oct. 26th, 1921	,, ,, 19th ,,
4.	,, ,,	March 3rd, 1922	,, ,, 16th ,,

It is probable that during winter the rust mycelium inside the host grows by fits and starts rather than remains altogether latent, because even in the middle of winter the weather may occasionally be favourable for its growth and fresh pustules may be formed.

That the recurrence of brown rust has a similar explanation will be clear from the following summary of experiments conducted during the spring, autumn and winter of 1921.

1. March 28th:
   (*a*) Wheat inoculated in the open and kept in the open — Pustules on the 15th day.
   (*b*) Wheat inoculated in tropical pit at the Botanic Garden — Pustules on the 8th day.

* Hecke, L., Naturw. Zeitschr. f. Forst- u. Landwirtsch. IX, p. 44 (1911).

2. October 26th:

Wheat inoculated in the open and kept in the open	Pustules on the 20th day.

3. December 9th:

(*a*) Wheat inoculated in the open and kept in the open	Pustules on the 36th day.
(*b*) Wheat inoculated in the laboratory	Pustules on the 10th day.

The question naturally arises, as to whether the black rust also can overwinter through its mycelium inside the host that may be infected in autumn. Observations on self-sown plants growing on the same plot unploughed, which had very badly diseased wheat till Oct.–Nov. 1920 show that it is very unlikely, whereas the same plot was full of self-sown plants bearing yellow and brown rusts in plenty. The same might be said about this rust on Couch grass.

The results of the following experiments on the incubation of black rust in the open suggest a similar conclusion.

October 26th, 1921:

Seedlings of rye inoculated in the laboratory at the Botanic Garden and removed to the open after two days—showed no pustules (till Dec. 19th); the inoculated spots became dried and shrivelled.

Control kept in intermediate pit. Pustules 12th day.

It may be remarked, for the sake of comparison, that wheat inoculated with yellow and brown rust on the same date and kept side by side with the above showed pustules within twenty days.

December 19th, 1921:

Rye inoculated in the laboratory at the Botanic Garden and removed to the open after three days; no pustules even after two months when most of the inoculated spots were dead.

Control kept in intermediate pit showed excellent infection within three weeks.

January 31st, 1922:

(*a*) Rye inoculated in intermediate pit and removed to the filmy fern house (very cool) after four days; pustules 24th day. Temp. of pit 40–50° F.; casually up to 60° F. or above in bright sun.

(*b*) Control. Pustules 10th day.

(*c*) Pot removed to the open. Pustules on the 30th day; only three out of twenty spots inoculated, developed pustules.

February 4th, 1922:

(*a*) Wheat inoculated and kept in unheated greenhouse. Pustules 25th day.

(*b*) Wheat inoculated in the laboratory removed to the open after four days. Pustules 27th day.

(*c*) Wheat inoculated in the laboratory and removed to unheated greenhouse. Pustules 22nd day.

(*d*) Control in the laboratory throughout. Pustules 10th day.

Average minimum temperature in shade during February 1922 was 33·5° F.

Average maximum temperature in shade during February 1922 was 48° F.

From the last two experiments it is clear that the mycelium of black rust can survive milder weather and but for the absence of the source of infection might appear on the cereal crops in the earlier part of spring, if weather conditions were favourable. But the source of infection (uredospores) cannot survive the more severe part of winter, and it is highly probable that the mycelium also cannot do so.

As there was no black rust available in the open, the material used for the above experiments was such as had been cultivated in the laboratory. In every case after inoculation the pots were kept indoors for two to four days before removal to the open, to give the fungus a good start. Still it was only in the experiments conducted in more favourable weather that any positive results were obtained.

That the incubation period may be prolonged even under higher temperatures is clear from what happened in one of the experiments last summer (1921).

Out of the six seedlings of Burbanks wheat inoculated with yellow rust in the laboratory on July 26th, and kept indoors under protection from direct sun, only one developed pustules, and that on the seventeenth day; other inoculated spots were dead and shrivelled by then.

Again Red Sudan wheat inoculated on August 8th with yellow rust and removed to the open after two days showed pustules on the eighteenth day but the infection was very poor.

Av. minimum temp. in July 53·8° F. Max. 79·4° F.
,, ,, Aug. 52·7° F. Max. 70·9° F. } in screen.

It may be remarked, that wheat inoculated on the 6th of June with yellow rust developed pustules on the ninth day.

The writer has great pleasure in being allowed to quote from the unpublished work of Dr Burns some interesting data which have a direct bearing on this question.

Dr Burns inoculated very susceptible varieties of wheat with black rust on the 16th of May 1909 at Poona in India, under the shade of a mango tree to protect seedlings from the hot sun and the plants developed pustules on the thirty-fifth day.

Average minimum temp. for May 73·5° F., max. 99·3° F.
" " " June 72·0° F., max. 86·2° F.

Similarly Ward*, Mains† and Fromme‡ have emphasised the influence of higher temperatures on the length of the incubation periods of other rusts. It is only fair to conclude, therefore, that the duration of the incubation period is exceedingly variable and that Eriksson evidently left out of consideration altogether the effect of temperature on the growth of the rust mycelium inside the host.

8. Culture of Rusts at comparatively low temperatures.

During the spring of the year 1922 some further experiments were conducted with the object of finding out the comparative duration of the incubation period in the case of all the three rusts cultivated at temperatures regulated to lie above the freezing point but not allowed to go very high. A constant record of the temperature of the greenhouse was kept with a thermograph and the average of daily temperatures was worked out by noting six readings per day. In all these experiments seedlings of Red Sudan wheat (which is very susceptible to all the three rusts) were used. The germination of spores was in every case found to be very good.

The lowest temperature recorded during the first experiment was 32·5° F. and the highest 72° F. In the second experiment it was 37° F. and 78° F. respectively. In the third it was 43° F. and 77° F. The weather during the course of the fourth experiment however was very warm and although the experiment was conducted in a cool greenhouse the lowest temperature recorded was 50° F., the highest being 82° F.

The results of these experiments are shown in the following table.

No.	Date at which the experiment was started	Range of average daily temperatures for the period. (The average for the whole period is shown within brackets)	Number of days after which pustules appeared		
			Yellow rust	Brown rust	Black rust
		° F.	Days	Days	Days
1	March 2nd	38·6 to 50·6 (40·0)	12–13	17–18	21–22
2	April 3rd	43·5 to 58·0 (50·8)	11–12	13–14	14–15
3	" 14th	48·5 to 58·8 (54·1)	8–9	8–9	11–12
4	May 18th	59·1 to 71·8 (66·5)	12–14	8–9	8–9

* Ward, H. M., Ann. Bot. xv, p. 560 (1901).
† Mains, E. B., Amer. Journ. Bot. iv, p. 179 (1917).
‡ Fromme, F. D., Bull. Torrey Bot. Club, xl, p. 501 (1913).

The above results clearly show that the optimum temperatures for the growth of the mycelium in the three rusts are different. Black rust undoubtedly flourishes better at higher temperatures and cold has a pronounced inhibitory effect upon its growth. The brown rust occupies an intermediate position, whereas the yellow one can flourish at low temperatures.

Further the results of the first experiment suggest a possible explanation of the sequence in the appearance of the yellow and the brown rusts. It has been pointed out that in this country yellow rust usually appears before the brown one. The reason why black rust does not appear till late in the season is that the source of fresh infection of cereals lies in the aecidiospores on barberry and the aecidial stage does not appear till late in spring.

9. Infection from Collateral Hosts.

Eriksson* has pointed out that the spread of rust from one kind of cereal or grass to another is considerably restricted on account of specialization of parasitism.

Similarly Butler† has remarked that wild grasses play no part in carrying rust in the main wheat growing tracts of India.

Stakman and Piemeisel‡ have stated that grasses aid materially in the spread of black rust on cereals. These authors have also remarked that, even if overwintering of this rust on grasses is infrequent, grasses may still be important because they may be nearer barberry bushes than are the grain fields.

As far as this locality is concerned the overwintering of black rust, whether on cereals or grasses, is very doubtful. The possibility of the fresh outbreak of the rust each year due to infection from other cereals or grasses is therefore out of the question. Besides it has been stated above that in wild grasses it has been observed only on Couch grass.

Yellow rust has been observed by the writer only once on *Agropyron repens* and *Agropyron caninum* but Miss Sampson sent some specimens of *Dactylis glomerata* from Aberystwyth which were found to be infected.

Speaking generally one might state that on account of a more rigid specialization of parasitism in the case of both brown and yellow rusts the possibility of other hosts playing a part in their perpetuation is limited. A detailed discussion of this question as far as this locality is concerned will be taken up in the second part of this paper.

* Eriksson, J., Bot. Gaz. xxv, p. 26 (1898).
† Butler, E. J., Fungi and Disease in Plants (1918).
‡ Stakman, E. C. and Piemeisel, F. J., Journ. Agr. Res. x, p. 429 (1917).

PART II.

SPECIALIZATION OF PARASITISM.

In recent years considerable work has been done on the biologic forms of rusts on cereals. In Europe Eriksson*, Eriksson and Henning† and Jaczewski‡ have made extensive investigations. In the United States Carleton§, Freeman and Johnson||, Pritchard¶ and quite recently Stakman and Piemeisel** have worked on different aspects of the question.

On account of the absence of any definite information on the subject for this country, and also on account of the bearing it has on the problem of the annual origin of rusts on wheat it was desirable that some investigations should be made. Further it is clear that in spite of the general agreement in the results obtained by various investigators there are interesting differences which have indicated the necessity for such work in different regions.

The present note deals with an account of some of the experiments conducted with the uredospores of black, brown and yellow rusts obtained on wheat in this locality. It also gives an account of some work done with the black rusts of barley and Couch grass (*Agropyron repens*) and the brown and yellow rusts of barley.

In order to avoid the use of impure material in the experiments a pure culture was invariably first established. Inoculations with different biologic forms were made in separate greenhouses.

Black rust from wheat (P. graminis tritici).

This biologic form was observed on tillers and self-sown plants of wheat on the Little Joss plot in October 1920 about a couple of months after harvest. It was established on wheat in November and since then its culture has been kept in the laboratory. The following is the table of results of inoculations with that material after its culture on wheat for six generations. In experiments (2) and (3) material used was respectively twelve

* Eriksson, J., Ark. f. Bot. I, p. 139 (1903); Ber. Deutsch. Bot. Gesell. XII, p. 292 (1894); Centralbl. f. Bakt. Bd. IX, Abt. 2, p. 590 (1902); Zeitschr. f. Pflanzenkrankh. IV, p. 66 (1894).

† Eriksson, J. and Henning, E., Die Getreideroste (1896).

‡ Jaczewski, A. A., Zeitschr. f. Pflanzenkrankh. XX, p. 321 (1910).

§ Carleton, M. A., U.S. Dept. Agric. Div. Veg. Phys. and Path. Bull. No. 16 (1899)

|| Freeman, E. M. and Johnson, E. C., U.S. Dept. Agr. Bur. Plant. Indus. Bull. p. 216 (1911).

¶ Pritchard, F. J., Bot. Gaz. LII, p. 169 (1911).

** Stakman, E. C. and Piemeisel, F. J., Journ. Agr. Res. X, p. 429 (1917).

and thirteen generations old. The spores showed good germination in every case.

Date	Hosts inoculated				
	Wheat	Barley	Rye	Oats	*Agropyron repens*
1921 Aug. 8th	$R\ \frac{4}{6}$ Heavy $En\ \frac{1}{5}$ Very weak	$B_{39}\ \frac{3}{5}$ Moderate $B_{25}\ \frac{2}{5}$ Weak	$\frac{0}{5}$	$E_{82}\ \frac{0}{5}$	$\frac{0}{10}$
1922 Feb. 10th	$R\ \frac{\infty}{\infty}$ Heavy $J\ \frac{4}{7}$ Moderate	$B_{39}\ \frac{3}{5}$ Moderate $B_7\ \frac{9}{13}$ Weak $B_{25}\ \frac{2}{6}$ Weak	$\frac{0}{8}$		
March 7th	$R\ \frac{\infty}{\infty}$ Heavy $En\ \frac{4}{13}$ Very weak	$B_7\ \frac{8}{11}$ Moderate	$\frac{0}{10}$	$E_{82}\ \frac{0}{10}$	

NOTE. In the above table *R*, *J* and *En* stand for varieties of wheat called Red Sudan, Little Joss and Einkorn respectively. B_{39} stands for a variety of Mesopotamian barley, B_7 for Archer barley, B_{25} for Webb's winter 6-row barley. E_{82} stands for a strain of Thousand dollar oats. The denominator in the fractions indicates the number of seedlings inoculated and the nominator the number actually infected. The nature of infection is also indicated. In the case of Einkorn wheat the pustules were exceedingly small and appeared much later than those on other hosts.

Seedlings of *Lolium perenne*, *Arrhenatherum avenaceum*, *Dactylis glomerata* and *Hordeum jubatum* were also inoculated along with others in the first experiment but none of them was infected.

Eriksson* has stated that in Sweden, barley, rye and oats are sometimes weakly infected by the black rust of wheat. The results of Stakman and Piemeisel† are quite in agreement with Eriksson's except that barley has been found to be a congenial host by these writers. As regards the wild grasses referred to above, Stakman and Piemeisel have stated that *Hordeum jubatum* is one of the hosts infected in nature by this biologic form and that *Agropyron repens* can be weakly infected by it. The same authors have observed that even rye is found infected by it in nature.

* Eriksson, J., Ber. Deutsch. Bot. Gesell. XII, p. 292 (1894); Centralbl. f. Bakt. Bd. IX, Abt. 2, p. 590 (1902); Zeitschr. f. Pflanzenkrankh. IV, p. 66 (1894).

† Stakman, E. C. and Piemeisel, F. J.. Journ. Agr. Res. X, p. 429 (1917).

Carleton* has however stated that rye and species of *Agropyron* are not infected by this form. Again Jaczewski† says that barley and *Lolium perenne* can be infected, but rye, oats and *Dactylis glomerata* are immune. Lastly Butler and Hayman‡ have also found that in India this form can infect barley.

This form has not been found in the locality under report on any other host except wheat. It will be clear from the above results that the specialization of this form is quite rigid and that among the cereals it infects only wheat (its original host) and barley. The capability to infect wild grasses is doubtful on account of the small number of trials made.

Amongst the varieties of wheat tried Red Sudan is exceedingly susceptible to this rust. Other varieties, Burbanks, Wilhelmina, Little Joss, Yeomen, Dreadnought, are all moderately susceptible. Squareheads master and American club are only weakly infected but Einkorn wheat is very highly resistant, though not altogether immune.

Amongst the varieties of barley tested, B_{39} (the Mesopotamian variety exceedingly susceptible to yellow rust) has been found to be far more susceptible than B_7, B_{25} or B_{66}. In order to find out if barley was a "bridging host" for this form seedlings of rye, oats, barley and Red Sudan wheat were inoculated with the material cultivated on barley (B_{39}). It is interesting to note that wheat (the original host) and barley were infected but rye and oats were not.

In February and March 1922 the writer inoculated on two different occasions seedlings of wheat, barley, rye and oats with uredospores of this form after their cultivation on Red Sudan wheat (exceedingly susceptible) for thirteen and fourteen generations respectively. Wheat and barley became infected but rye and oats were quite immune.

The writer is in complete agreement with Stakman, Piemeisel and Levine§ and Stakman, Parker and Piemeisel‖ who have stated that the pathogenicity of biologic forms is not changed by bridging hosts or by association with a given host. The form under discussion did not acquire any new parasitic capability even after its continuous cultivation for over sixteen months on Red Sudan wheat. Puttick¶ has also pointed out that the parasitic

* Carleton, M. A., U.S. Dept. Agric. Div. Veg. Phys. and Path. Bull. No. 16 (1899).

† Jaczewski, A. A., Zeitschr. f. Pflanzenkrankh. XX, p. 321 (1910).

‡ Butler, E. J. and Hayman, J. M., Mem. Dept. Agric. India, Bot. Ser. I, No. 2 (1906).

§ Stakman, E. C., Piemeisel, F. J. and Levine, M. N., Journ. Agr. Res. XV, p. 221 (1918).

‖ Stakman, E. C., Parker, J. H. and Piemeisel, F. J., Journ. Agr. Res. XIV, p. 111 (1918).

¶ Puttick, G. F., Phytopathology, XI, p. 205 (1921).

capabilities of the biologic forms that he worked with were constant.

Black rust of Agropyron repens (P. graminis secalis).

This biologic form has been found only on Couch grass (*Agropyron repens*) in this locality. It is probable, however, that the form found on barley which will be dealt with later is identical with it. The following table gives the results of inoculations with uredospores. In experiment No. 1 the material used was such as had been cultivated on Couch grass for one generation. In other experiments the material used had been cultivated on rye for two, three, five and six generations respectively.

Date	Hosts inoculated				
	Agropyron repens	Rye	Wheat	Barley	Oats
1921 Aug. 11th	$\frac{5}{10}$ Moderate	$\frac{6}{6}$ Heavy	$R\ \frac{4}{7}$ Very weak $En\ \frac{0}{6}$	$B_{39}\ \frac{6}{6}$ Good $B_{25}\ \frac{2}{6}$	$\frac{0}{6}$
Aug. 30th	—	$\frac{4}{6}$ Heavy	$R\ \frac{2}{4}$ Very weak	$B_{39}\ \frac{3}{3}$ Good	$\frac{0}{4}$
Sept. 13th	—	$\frac{5}{5}$ Heavy	$R\ \frac{2}{5}$ Very weak	$B_{37}\ \frac{3}{7}$ Weak	$\frac{0}{4}$
1922 Jan. 24th	—	$\frac{27}{29}$ Heavy	$R\ \frac{7}{11}$ Very weak $J\ \frac{0}{10}$	$B_7\ \frac{8}{14}$ Weak	$\frac{0}{12}$
Feb. 25th	—	$\frac{12}{15}$ Heavy	$R\ \frac{8}{13}$ Very weak $J\ \frac{0}{10}$	$B_7\ \frac{5}{11}$ Weak $B_{25}\ \frac{4}{10}$ Weak	—

NOTE. The varieties used are the same as tried with the biologic form of wheat. For the cultivation of this form seedlings of rye were found to be more convenient than those of Couch grass (the original host).

Along with the first experiment seedlings of *Dactylis glomerata, Lolium perenne, Arrhenatherum avenaceum* and *Hordeum jubatum* were also inoculated but none of them became infected.

Eriksson* has found that this form infects rye, *Agropyron repens, Hordeum jubatum,* barley and some of the grasses but not wheat and oats. Eriksson and Henning† have recorded that inoculations with material from rye infected rye and barley but not oats and wheat. Jaczewski‡ in Russia has remarked that *Dactylis glomerata* can be infected and that barley, wheat and oats are immune.

* Eriksson, J., Ber. Deutsch. Bot. Gesell. XII, p. 292 (1894).

† Eriksson, J. and Henning, E., Die Getreideroste (1896).

‡ Jaczewski, A. A., Zeitschr. f. Pflanzenkrankh. XX, p. 321 (1910).

Again Stakman and Piemeisel* in the United States have stated that this form is found on *Agropyron repens*, *Hordeum jubatum*, barley, rye and some other hosts in the field. The same authors succeeded in infecting barley easily but not *Dactylis glomerata*, *Lolium perenne* and *Arrhenatherum avenaceum*, etc. As regards wheat these authors have remarked that it is very rarely or scarcely at all infected by this form. Out of four hundred and fifty-four trials according to their data only three gave positive results. These authors state that oats also can be rarely and weakly infected.

It will be seen that it has been possible to infect *Agropyron repens* (the original host), rye, barley and contrary to what has been reported from other regions, even wheat (at least the variety Red Sudan). Oats are not infected. About the grasses mentioned above the writer is doubtful (on account of the small number of trials) if they can be infected by this form.

As regards Red Sudan (wheat) infected by this form positive results were obtained in twenty-nine cases out of fifty with undoubtedly a pure culture (after cultivation on rye for twelve generations). The size of the uredo-sori developed on wheat was invariably much smaller than those on rye or barley.

Inoculations with material as many as ten and eleven generations old was also tried on other varieties of wheat—Little Joss, Burbanks, Yeomen, Dreadnoughts, Squareheads master, American Club and Red Sudan and rye (as controls). Only rye and Red Sudan became infected and all other varieties of wheat were found to be immune. This fact can easily be explained on account of the exceedingly susceptible nature of Red Sudan. From over 50 % cases of successful infection one cannot but conclude that the specialization of this form is not absolutely rigid as far as wheat is concerned. It is not possible at this stage to make any definite statement on the possibility of wheat taking infection from Couch grass or rye in the open. As far as barley is concerned there is not the slightest doubt that Couch grass, on account of its plentiful distribution, may not only be responsible for the spread, but on account of its proximity to barberry may even be the cause of the fresh outbreak of black rust on that cereal.

As shown in Table, p. 170, the variety most susceptible to this form is B_{39} (Mesopotamian barley). The other varieties are not so susceptible. It is interesting to note that the same varieties are only moderately susceptible to the black rust of wheat also.

This form too was cultivated on barley (B_{39}) for two generations and inoculations were made on rye, barley, Red Sudan and oats with that material. Rye, barley and Red Sudan were

* Stakman, E. C. and Piemeisel, F. J., Journ. Agr. Res. x, p. 429 (1917).

infected but oats were immune showing that barley cannot change the infection capability of this form either.

Black rust of barley.

In August 1921 this rust was found at the farm with the infected bushes of barberry referred to in Part I. Black rust was noticed on *Agropyron repens* a few weeks earlier on the same farm.

The following table shows the results of inoculations with a pure culture of this form.

Date	Original host	Immediate host	Hosts inoculated				
			Barley	Rye	Wheat	Oats	*Agropyron repens*
1921 Sept. 4th	Barley Archer	Barley B_{39}	B_{39} $\frac{3}{4}$ Moderate	$\frac{4}{4}$ Heavy	$\frac{0}{5}$	$\frac{0}{4}$	$\frac{2}{4}$ Moderate

Eriksson* has stated that the black rust of barley can infect rye and barley but not oats and wheat. Jaczewski† on the other hand has found that uredospores from barley can infect barley, Couch grass and wheat but not oats and rye. According to his results the forms on barley and wheat seem to be identical in Russia.

Again Stakman and Piemeisel‡ have remarked that black rust of barley infects wheat more readily than rye and that oats are not infected by it.

It has been shown above that the black rust of *Agropyron repens* can infect wheat (Red Sudan) and rye, but the black rust of wheat cannot infect rye. Since the black rust of barley can infect rye readily and also Couch grass, it seems highly probable that this form is different from the form on wheat. Most probably the form on barley is identical with the form on *Agropyron repens* (f. sp. *secalis*). In the last table it has been shown that this form failed to infect wheat (Red Sudan) which is infected by the form on *Agropyron repens*. Unless the form on barley too can infect Red Sudan wheat its exact relation with f. sp. *secalis* cannot be established. Unfortunately the culture of this form was lost and on account of the uredo-stage being so rare later on it could not be re-established. Further trials with this were not possible.

It is obvious that apart from slight local differences speciali-

* Eriksson, J., Ber. Deutsch. Bot. Gesell. XII, p. 292 (1894); Zeitschr. f. Pflanzenkrankh. IV, p. 66 (1894).

† Jaczewski, A. A., Zeitschr. f. Pflanzenkrankh, XX, p. 321 (1910).

‡ Stakman, E. C. and Piemeisel, F. J., Journ. Agr. Res. X, p. 429 (1917).

zation is not quite so fixed as far as black rust is concerned. Barley, as has already been pointed out by Stakman and Piemeisel, is infected by all the six forms that these authors have worked with. Again rye has been reported in other regions to be infected by the form on wheat. In this locality wheat has been repeatedly infected with the form on Couch grass. It seems likely that in every class of cereals there are certain varieties, which are undoubtedly susceptible to one or more biologic forms of this rust, other than the one to which they are said to be restricted. Probably the differences in specialization recorded from different regions are largely due to the fact that the various investigators have been working with different varieties. To illustrate this fact one may say that some more susceptible variety of rye may be infected by the form on wheat in this locality. Again the variety of wheat (Red Sudan) may be infected by the form on rye or Couch grass in other countries too.

Brown rust of wheat (P. triticina *Erikss. and Henn.*).

Eriksson* has found that this form can sometimes infect rye. The writer made some inoculations with a pure culture on wheat, rye, barley and *Agropyron repens*. Barley and *Agropyron repens* were not infected, wheat showed very good infection and out of twenty-one seedlings of rye three were infected. The results are thus in complete agreement with those of Eriksson as regards the casual infection of rye with the brown rust of wheat.

Brown rust of rye (P. dispersa *f. sp.* secalis *Erikss. and Henn.*).

This form has been found by Eriksson* to be altogether specialized on rye. The same has been found to be true in this locality. Inoculations with a pure culture were made in August 1921, and in both the trials it was found that barley, wheat (Red Sudan) and *Agropyron repens* were not infected, whereas rye inoculated on both occasions showed heavy infection.

The dwarf brown rust of barley (P. simplex *Erikss. and Henn.*).

Some inoculations were made in August 1921 with a pure culture of this rust, on wheat (Red Sudan), rye, *Agropyron repens* and barley; only barley was infected. This rust too seems therefore to be quite specialized.

Yellow Rust.

In this rust also there is strict specialization of the different biologic forms as pointed out by Eriksson†. The writer

* Eriksson, J., Ann. Sc. Nat. sér. 8, IX, p. 241 (1899).
† Eriksson, J., Ber. Deutsch. Bot. Gesell. XII, p. 292 (1894).

made several inoculations with a pure culture of the yellow rust of wheat and found that barley and rye are not infected by it. Some experiments with the yellow rust of barley were conducted in the summer of 1921, but on account of very hot weather the infections were unsuccessful even on barley itself, and the pure culture was lost. Yellow rust was noticed on rye in this locality last summer (1921) but an attempt to establish a culture failed on account of the great heat, nor was it possible for any work to be done with the form on Couch grass.

I wish to express my warmest thanks to Mr F. T. Brooks, under whose supervision these investigations have been made, for advice and the interest he has taken in their progress. I am also very grateful to Mr F. L. Engledow and Mr S. F. Armstrong of the School of Agriculture for having provided me with seeds of the different varieties of cereals used in the experiments.

August 1922.

10. Summary.

Part I.

(*a*) *Black rust* (P. graminis).

(1) Fresh uredo-sori of this rust are not found after the commencement of winter. Uredospores in old pustules exposed to winter cold soon lose their viability.

(2) Observations and experiments show that this rust cannot overwinter in this locality even as mycelium inside the host plants.

(3) Direct infection of wheat by sporidia is not possible.

(4) There is no evidence to show that this rust can originate from "mycoplasm" or from intra-seminal sori.

(5) The annual outbreak of this rust can be explained only by fresh infection through aecidiospores produced on barberry.

(*b*) *Brown and yellow rusts* (P. triticina *and* P. glumarum).

(6) Fresh uredo-sori of the brown rust of wheat and the dwarf rust of barley are found during the greater part of winter. Uredospores from the open during winter always show good germination.

(7) Fresh uredo-sori of the yellow rust of wheat were found during the greater part of the winter of 1920–21. Uredospores from such pustules always germinated well.

(*c*) *Incubation period.*

(8) For the annual recurrence of rusts the factor of the greatest importance is the occurrence of plenty of uredospores on self-sown plants and tillers at the time when the autumn sown crop appears. The infection of young seedlings is followed by

a comparatively long incubation, the exact duration of which is dependent upon conditions of weather—temperature being the chief regulating influence.

(9) The length of the incubation period is not only not fixed at eight to ten days but is very variable. Although the last two seasons were comparatively mild the incubation period in some of the experiments was prolonged to five to six weeks.

(10) These facts also suggest a satisfactory explanation of the phenomenon of spontaneous outbreaks (so characteristic of yellow rust) over large areas within the space of a few days.

(11) Cultures of all the three rusts at comparatively low temperatures show the shortest incubation period for the yellow rust and the longest for the black one. A clear difference between the duration of the incubation periods of yellow and brown rusts suggests the cause of the usually earlier appearance of the former.

(*d*) *Influence of temperature on the viability of uredospores and the growth of the mycelium.*

(12) The uredospores of black rust retain their viability at comparatively high temperatures. Those of yellow rust suffer most from heat and are more viable when kept at lower temperatures. The uredospores of brown rust however combine the powers to resist cold as well as heat.

(13) The uredospores of yellow rust are short lived and are impaired at temperatures which both black and brown rusts can withstand.

(14) Higher temperatures are inhibitory to the growth of the mycelium of yellow rust, and therefore prolong the duration of the incubation period, and may even kill the mycelium.

(15) Some of the most susceptible varieties of wheat and barley even when exposed in the open for over ten months do not become affected by yellow rust if the viability of the uredospores (the only source of infection) is impaired.

(16) The observations and experiments recorded in this paper deny all possibility of an hereditary source of infection and offer an adequate explanation of the annual recurrence of these rusts.

Part II.

Inoculation experiments with pure cultures of the following biologic forms showed that:

(1) The black rust of wheat can infect only wheat and barley, but does not infect rye and oats.

(2) The black rust of Couch grass readily infects Couch grass, rye and barley, and contrary to what has been observed at other places can also infect one variety of wheat (Red Sudan).

(3) The black rust of barley infected barley, rye and Couch grass but failed to infect wheat. This form is different from that on wheat and probably is identical with that on Couch grass.

(4) As far as black rust is concerned specialization is not quite so fixed as has been recorded elsewhere. In this locality Couch grass infected with this rust may be a source of danger to barley.

(5) The brown rust of rye is rigidly specialized to its host.

(6) The brown rust of wheat casually infects rye.

(7) The dwarf rust of barley and the yellow rust of wheat cannot infect other cereals.

THE LITERATURE ON THE CLASSIFICATION OF THE HYSTERIALES.

By G. R. Bisby.

The group of the Ascomycetes known as the Hysteriales is at present commonly considered to include a large number of forms characterized by fruit-bodies (known usually as perithecia or apothecia) which open tardily by a longitudinal fissure. The accretion of forms into this group is reflected by Saccardo, who gives, in volumes II, IX, XI, XIV, XVI, XVII and XXII of the *Sylloge Fungorum*, seven hundred and three references to the Hysteriaceae and thirty-eight to the Hemihysteriaceae, included in a total of fifty-one genera. Eliminating duplicate, varietal, and revoked references, there remains a total of some six hundred and seventy species in forty-six genera in these two related groups in the *Sylloge*, and many species have of course been described too recently to be included.

The writer has gone over the scattered literature in an attempt to set forth the ideas of classification held by various workers on this group. The knowledge of these fungi has, of course, undergone much development during the past two centuries, but the Hysteriales are still comparatively poorly understood.

Few early botanists devoted much attention to the fungi, and even when fungi were noted, the conspicuous forms naturally received first attention. The hundreds of Hysteriales, Pyrenomycetes, Lichens, and other small, undescribed fungi which occurred in the woods and fields would either be unnoticed, or could be described only vaguely prior to the close of the 18th century. Certain Hysteriales and other fungi were included in

some of the early descriptions of lichens. Thus Ray (1, p. 71) may have observed one of the Hysteriales; he gave the following description in 1724: "48. Lichenoides crusta tenuissima, peregrinis velut litteris inscripta. Found by *Dr Doering* at *Westerham*, a little beyond the Schoolhouse on a Tree in the Lane, that leadeth to *Querry's* in *Kent*." There is nothing very distinctive about this description, which would probably more aptly apply to certain lichens, but the Latin diagnosis was quoted verbatim by Micheli, Dillenius, Linnaeus, Haller, and others, and after modification and elaboration came finally to be involved in the synonymy of *Hysterium pulicare*, and also in the synonymy of the lichen *Graphis scripta*. In other words, various writers following Ray considered that the material they examined agreed with the general description Ray had given, or with the descriptions subsequent writers had elaborated from Ray's description and an examination of other material, until finally a definite plant could be recognised.

Micheli (2, p. 102) described: "7. Lichen crustaceus, tartaricus, arboribus adnascens, niger, & veluti deustus, receptaculis florum transverse oblongis, & quasi reniformibus non intortis, brevibus. Tab. 54. fig. 2. Per ambulacrum Imperialis villae in Ilicum cavernulis late se diffundens." This is referred to by Lightfoot and others as noted below. Micheli quoted Ray in No. 9, and noted "receptaculis florum sub cute erumpentibus, nigricantibus, transverse oblongis, varie divarigatis, & compressis." His numbers 10 and 11 are noted by Dillenius and Linnaeus.

Dillenius (3, p. 125) quoted Ray, gave figures, and noted: "Pertenui constat crusta albicante, cui variae figurae lineae inaequales, nigrae,...sunt....Nec tubercula nec scutellae aliquae mihi visae sunt." He stated that this plant occurred on elms and oaks and considered Micheli's Nos. 9, 10 and 11 to be no more than varieties. Dillenius followed with "2. Lichenoides punctatum & rugosum nigrum. The black dotted wrinkled Lichenoides. Crusta est tenuissima candida, cui maculae transversim innascuntur nigrae, pro arborum aetate & magnitudine majores & minores, nunc ex punctis elevatis, velut tuberculis quibusdam parvis, nunc ex lineis oblongis, tanquam rugis, dense congestis conflatae. Quae rugae vel non, vel parum ramosae sunt, linea vel sulco in medio (per lentem) destitutae, secus ac in praecedenti specie. A qua porro differt, quod puncta & rugae densius congestae sint." This form he reported on beech and oaks where the bark was still smooth and equal.

Haller (4, p. 188) listed: "Lichen bivalvis de rimis efflorescens, ater, characteristicus," followed by Ray's words, but with reference only to "Dill. t. 18. f. 1."

Linnaeus (5, p. 343) in 1745 merely brought together these

previous descriptions in his "941. Lichen leprosus albicans, lineolis nigris characteriformibus," and quoted Ray, Dillenius' No. 1, and Micheli's No. 9, and included Micheli's Nos. 10 and 11 (following Dillenius) as varieties. In *Species plantarum* (VI, p. 1140) Linnaeus gave this the binomial *Lichen scriptus*, and the name *Lichen rugosus* to Dillenius' No. 2, with the description "Lichen leprosus albicans lineolis simplicibus punctisque nigris confertis."

References to these species of Linnaeus were given in a number of the Floras that were so commonly published by various workers who followed Linnaeus, but in most of these no new data that enlighten us regarding the Hysteriales are found.

Lightfoot (7, pp. 800, 801) in 1777 gave the following suggestive notes:—"[Lichen] scriptus. 1. Lichen leprosus albicans, lineolis nigris ramosis characteriformibus. Sp. pl. 1906. Micheli gen. t. 56 f. 3. Dillen. musc. t. 18. f. 1.

"On the smooth bark of trees, frequent, as on beech, oak, hornbeam, etc. This is readily distinguished by its black fructifications, resembling small oriental characters, which, under the microscope, appear to be longitudinally wrinkled.

"There are two very remarkable varieties of this lichen, which might perhaps be more properly considered as distinct species:

"Hebraicus α. The first has large black, smooth fructifications, standing in high relief, of no regular figure, but from their size and thickness have a rude likeness to Hebrew characters. *Fig. non inveno.*

"Pulicaris β. The other consists only of small black, oval tubercles each about the size of a flea, having a longitudinal furrow on the back. It grows generally in the crevices of the bark of old oaks. The figure of Micheli agrees with it. Gen. pl. t. 54. ordo 37. f. 2.

"Neither of these two last are in Dillenius's collection at Oxford." The specimens upon which Lightfoot based the above descriptions could not be found in the Lightfoot herbarium at Kew.

Wiggers (8, p. 86) transferred *Lichen scriptus*, *L. rugosus*, and others to his genus Verrucaria. Hoffman (9, p. 14) made Lightfoot's varieties into species. His figures (t. 3. fig. 2, e, f) are uncertain.

Bulliard (10, p. 187) figured and described rather indefinitely *Variolaria corrugata* on the bark of branches, and (p. 170) *Hypoxylon ostraceum*, both of which may have been Hysteriales.

Tode (11) in 1783 described *Acrospermum unguinosum* but the genus is usually stated to date from his 1790 work. In 1784 (12) he applied the name Hysterium to a fungus which he described

as "Fungus labiatus sessilis per labia distenta semen nudum superficiale ejaculans" with the species *H. quadrilabiatum.* He gave this the common name "Venusschwämme." No previously described similar species were mentioned. In 1790 (13, p. 8) *Acrospermum compressum* and two other new species were described and (p. 30) *Hysterium bilabiatum.* In 1791 (14, pp. v, vi, 3–5) he explained that *H. quadrilabiatum* proved to be, on further study, a weathered or altered Sphaeria, and he was uncertain about *H. bilabiatum,* so he re-described the genus as "Fungus oblongo-acuminatus, cavus, sessilis, linea transversali superne findendus, seminibus globoso-ecaudatis, discum obducentibus" and observed "medium hoc genus inter Pezizas & Lichenes." He referred to *Lichen scriptus* L. and to Wiggers and Hoffman. Three new species were described and figured. The genus Hysterium is usually stated to date from this revised description of it in 1791.

Bolton (15, p. 124, fig. cxxiv) described *Sphaeria sulcata,* giving Lightfoot's variety β as a synonym, and observed that "This is a small, black, oblong tubercle, the size of a small flea; it is prominent, and has a deep furrow along the back, from end to end, by which it seems as if cloven in two, but the ends are joined together at the base....The plant under the double magnifier appeared like a bivalve shell, when closed and seen in front...on twigs and branches of ash trees, when in decay." He gave good figures of the external appearance of the fungus.

Acharius (16, p. 20) in 1798 described *Lichen alneus* on the bark of old Betula and Alnus, and *L. elatinum,* both of which subsequent authors considered to be Hysteriales. Under *Lichen scriptus* he listed a total of twenty-nine author citations. These included, in addition to certain authors noted above, those who had compiled Floras and included this name. In 1810 (17, p. 265) Acharius changed the name to *Graphis scripta.* In 1814 (18) he described several species of Opegrapha, which were later transferred to species of Hysteriales.

Persoon (19, p. 83) listed *Hysterium nigrum* Tode, *Variolaria corrugata* Bull. and *Lycoperdon vulvatum* Latourette as synonyms of his *Hysterium quercinum,* and included, without synonyms, three other new species of Hysterium. In *Synopsis methodica fungorum* (20, p. xii, 98, etc.) he included Hysterium with Sphaeria, etc., in his order Sclerocarpi of the class Angiocarpi. Hysterium is described briefly as "perithecium oblongum, rima longitudinali dehiscens," and nineteen species are given. *Lichen scriptus β pulicaris* Lightf. and "Mich. Nov. gen. pl. t. 50, f. 2" are given as synonyms for *H. pulicare, Sphaeria sulcata* Bolt. for *H. Fraxini,* and the synonyms given above for *H. quercinum,* except that Latourette's species is omitted. (Latourette had

listed the name without description, in *Chloris Lugdunensis*, 1785). The genus Hysterium was considered in a broad sense by Persoon, and subsequent workers, especially upon examining the spores, placed certain of the species in other genera. Certain species of Xyloma as described by Persoon were also subsequently removed to the Hysteriales. Species of Acrospermum were placed by Persoon in the genus Clavaria. In *Mycologia Europaea* (21, p. 331) Persoon described Tryblidium.

Persoon brought together a number of similar fungi into the genus Hysterium, and made a considerable advance in systematizing the knowledge concerning certain forms which had previously been overlooked or placed in the lichens or in various genera of fungi. The workers up to, and even including, Persoon, had naturally not been able to make much headway with these fungi, since the internal, microscopic characters were still almost unknown. Rapid progress was soon made and it is unnecessary to attempt to follow the specific, or even later generic, changes that came to be made, but the systems of classification and development of knowledge may be followed in a general way.

Sowerby (22) illustrated and gave notes on several forms. Albertini and Schweinitz (23) followed Persoon.

De Candolle (24, p. 280) gave the name "Hypoxyla" to a group of genera including Sphaeria, Xyloma, Opegrapha, Verrucaria, Hysterium and Hypoderma. This last genus was described as new, for subepidermal Hysteria, and five species of Hysterium were transferred to it.

Muehlenberg (25, p. 101) listed *Glonium stellare* without description. The genus was later described by him in Fries (27). Nees (26, Ueberblick, pp. 72–86) included Antennaria, Hysterium, Sphaeria, Thelobolus and Nemaspora in his group Myelomyci (Kernschwämme).

Fries (27) in his *Systema Mycologicum* proposed the name Pyrenomycetes, with Xylomyci Willdenow, Sclerocarpi Persoon, Hypoxyla De Candolle, and Goniomyci and Myelomyci Nees, as synonyms. He included as orders Phacidiacei, Sphaeriacei, Cytisporei, and Xylomacei, but noted that the Phacidiacei were aberrant in that they were often cupulate, but had the general habit of Pyrenomycetes. Under the Phacidiacei he included Hysterium Tode (including Hypoderma DC.) with forty-eight good species, three more doubtful, four listed as aberrant, and some twenty other species were transferred, discarded, or noted; Glonium (under Muehlenberg's name) with *G. stellatum*: Actidium with two species; and the genera Rhytisma, Phacidium and Excipula. Lophium he included under Sphaeriacei. Acrospermum was placed in the Sclerotiacei of the Gasteromycetes.

In 1825 (28) Fries altered somewhat his classification of the Pyrenomycetes. He included under Sphaeriacei a sub-order Dichaenei with his genera Dichaena and Ostropa, and under Phacidiacei the sub-orders Patellarei including, among others, Tryblidium; Cenangei; Cliostomei including Glonium, Lophium and Actidium; and Phacidiei, including Hysterium. He noted for Hysterium that "Nominis Auctor est Tode, sed nulla illius species huc pertinet." In reality, as von Hoehnel (76) points out, the name should be cited as Hysterium Fries.

In these two works and in *Observationes Mycologicae* (29) and *Elenchus fungorum* (30) Fries gave various synonyms and author citations, including many of the authors previously mentioned in this summary. He did not pay much attention to spore characters in his descriptions of these fungi. Fries' later ideas are given below.

Brongniart (31, p. 93) included the "Tribes" Sphaeriacées (including Lophium) and Phacidiacées in the Hypoxylées.

Greville (32, Vol. II, pl. 167) in 1825 gave excellent plates of several Hysteria. He figured, for the first time, the asci and spores of certain forms. Greville placed Lophium with Hysterium in the Tribe Phacidiei of the order Phacidiacei. Acrospermum was included (Vol. VI) in the Gasteromycetes.

Chevallier (33) revived De Candolle's name Hypoderma, and transferred three species from that genus to his new genus Lophoderma. In 1826 (34, p. 432) Chevallier proposed the order Hysterineae to include Lophium, Hysterium, Lophodermium (as he spelled it here) and his new genus Schizoderma (? = Dichaena Fr.). This order he placed in his class Cheilomycei. Acrospermum he included in the Sclerotiaceae. Chevallier placed Leptostroma, Actinothyrium, Phacidium, Eustegia, Rhytisma, and Phoma in his order Rhytismaceae.

Schweinitz (35, 36) described for North America forty-three new species in Hysterium, Dichaena, Ostropa, Lophium, Glonium and Actidium, out of a total of sixty-seven species in these genera, which he considered to occur in his collections. Since he did not describe the asci and spores of these forms, much uncertainty still exists as to the nature of his species. Acrospermum was placed in his earlier work in Tremella. Schweinitz followed Fries' classification in his later work.

Duby (37, Vol. I, p. 718) followed Brongniart's classification. His later work is noted below.

Wallroth (38, p. xxix) included Xyloma, Phacidium, Tryblidium, Colpoma (a genus he described to include *Hysterium quercinum* Pers.), Lophium, Hysterium, Stictis, and Peziza in the Hymenomycetes of Fries.

Fries, in his *Epicrisis* (39, p. 1) proposed the name Discomycetes,

and in 1835 (40, p. 344) placed the Phacidiacei (including Glonium, Actidium, Hysterium, Phacidium, Rhytisma, and Leptostroma) in this class. The Dichaenei (including Actidium, Lophium, Ostropa and other genera) he left in the Pyrenomycetes, but noted "Transitum sistunt ad Discomycetes, sed discum verum non monstrant." (Actidium he included in both groups.) In 1849 (41, pp. 367, 400) he maintained the same general arrangement.

Mlle Libert (42) described Aylographum, and included it with Hysterium, Glonium, Actidium, etc., in the section Phacidiacei of the Xylomyci. Nees and Henry (43) and Rabenhorst (44) followed Fries.

Corda (45, 46) in 1842 gave the name Hysteriaceae to a family of his order Myelomycetes. The Hysteriaceae he subdivided into Stegiaceae (with Stegia), Hysteriaceae (including Ailographum, Hysterium, Sporomega Corda, and Lophium), Gloniaceae (with Hysterographium Corda and Glonium), Cliostomei (with Cliostomum and Actidium), and Phacidiei (including Phacidium, Heterosphaeria, and Rhytisma). Ostropa and Dichaena were placed in the Sphaeriacei. Spore characters were taken into consideration and several species were illustrated.

De Notaris (47) in 1844 considered spore characters further and made these the basis of classification of the Hysteriaceae. He divided the family into two sections: Phaeosporii, with Triblidium, Hysterium and Hysterographium, and Hyalosporii, with his Gloniopsis, and ten other genera. As the title indicates, these fungi were considered to be Pyrenomycetes.

Léveillé (48, p. 115) proposed Thécasporés as a division of Fungi, with subdivisions Ectothèques and Endothèques. The latter was divided into Tribes Rhegmostomés (including sections Hystériés and Cliostomés), Stégillés and Sphaeriacés.

Bonorden (49) followed Corda's classification.

Berkeley (50) proposed the name Ascomycetes for Léveillé's Endothèques. He (51, p. 379), however, followed Fries and other earlier workers in including Hysterium and other genera in the Phacidiacei.

Duby (52) in 1862 published his memoir on the Hysteriales. He considered that these fungi should be placed with the Pyrenomycetes for the following reasons: (1) the perithecia are horny or cartilaginous, (2) the perithecia are elliptical or linear, (3) they show a special method of dehiscence. He considered that the Hysteriales showed affinities with the Discomycetes (Pézizées) through Triblidium. Duby reviewed his previously stated ideas of their relations to, and differences from, the Lichens. He points out that Coemans had noted that the hymenium of the Hysteriales gives no reaction with iodine.

In discussing the value of diagnostic characters in the Hysteriales, Duby considered that de Candolle's separation on the basis of superficial or imbedded, and de Notaris' use of the colour of spores, were not of great value. Duby divided the Hysterineae into two sections, Lophiées and Hystériées, and made further subdivisions on the basis of dehiscence of asci. Under Lophiées he included Lophium as having dehiscent asci, and his new genera Ostreichnion and Mytilinidion as having indehiscent asci. In the section Hystériées he included Triblidium, Hysterium, Glonium, Aylographum, Hypoderma, Angelina, and Actidium with indehiscent asci, and Lophodermium, Sporomega, Coccomyces, Colpoma and Ostropa under dehiscent asci. Duby made a new genus Aporia, which he considered "anomalum et ambiguum." He gave generic and specific descriptions of the various forms, and illustrated twenty-five species. His division of genera on the basis of dehiscence of asci has not been followed.

The Tulasne brothers (53, Vol. I, p. 224; II, p. 258; III, p. 111) gave notes on several forms and illustrated one. In their classification they included the genera under Phacidiei. L. R. Tulasne (54) also recorded observations on the "spermagonia" of certain Hysteria.

Since 1865 there have appeared many works containing classifications, or revision of classification, of Fungi. Chevallier (33) had long since suggested a grouping which separated the Hysteriales from the Phacidiales, but Fries and many others had included the Hysteriales as a subdivision of the Phacidiales. Corda's suggestion of reversing the terminology and including Phacidiei under Hysteriaceae had not been followed. De Notaris (47) and Duby (52) had considered the Hysteriales as a distinct group, as did de Bary (55, pp. 190 etc.). Fuckel (56, p. 248) and Cooke (57, p. 750) followed Fries and included the Hysteriales with the Phacidiales in the Discomycetes. In a later paper Cooke (58) followed Duby.

Saccardo at first (59) followed in general the classification of Fries for these fungi, but later (60) carried de Notaris' (47) basis of classification on spore characters further and divided the Hysteriales into the Sections Hyalosporae, Didymosporae, Phragmosporae, Scolecosporae and Dictyosporae, placing them in the Pyrenomycetes. Spegazzini (61) elaborated further this idea in his "nova systematis carpologici dispositio," and classified the Hysteriales into Aplosporae, Didymosporae, Phragmosporae and Dictyosporae, each group being divided again into Hyalosporae and Phaeosporae. Thus, for example, the Aplosporae-Hyalosporae included the genera Aporia and Hypoderma. The Hysteriales he placed in the Angiothalamae (Pyrenomycetes). In 1883 (62) Spegazzini proposed the Hemihysteriaceae

with Morenoëlla, Schneepia and Hysterostomella, and he has added also other genera and species to the Hysteriales from his South American collections. In the *Sylloge* (Vol. II, p. 721) Saccardo modified his and Spegazzini's classification, and made nine sections, using descriptive words with Hyalo- and Phaeo- as prefixes.

Gillet (63) included the Phacidiales but not the Hysteriales in his work on the Discomycetes. Ellis and Everhart (64) included the Hysteriales in their work on North American Pyrenomycetes, although they remark that they had not at first intended to do so.

In Engler and Prantl, *Pflanzenfamilien*, Schroeter (65, p. 2) included the Hysteriineae, but not the Phacidiineae, in the Pyrenoasceae, but further on (p. 142) he included both these orders in the Discomycetes. Lindau (pp. 265–278) described the group, dividing it into five families. He noted that "Die Hysteriineae bilden eine Mittelgruppe" connected with the Phacidiaceae on one side and Lophiostomataceae on the other, being also similar to the Graphideae.

Rehm (66) went over Duby's collection and revised various forms. In Rabenhorst's *Kryptogamen-Flora, Die Pilze*, Rehm (67) discussed relationships, placing the order Hysteriaceae as a separate group between the Discomycetes and Pyrenomycetes. He classified the genera into three families, Hysterineae, Hypodermieae, and Dichaenaceae, with an "Anhang," Pseudohysterineae Rehm, to include Acrospermum. Several genera previously included in the Hysteriales were removed to the Pezizales. Rehm at various times added to the knowledge of the group (68, 69).

Boudier (70) did not include the Hysteriales in his work on the Discomycetes but Schroeter (71) and Seaver (72) so classified them.

Clements (73) in 1909 used the term "hysterothecium" for the fruit body of the Hysteriales and Graphidaceae.

During the past few years fundamental changes in the arrangement of the Pyrenomycetes and Hysteriales have been proposed. Theissen and Sydow (74) included several genera, which had been included in Hemihysteriaceae or Hysteriaceae, in their work on the Dothideales, and von Hoehnel (75) in 1918 removed several genera to the Phacidiales. In various of his *Mycologische Fragmente* von Hoehnel has given critical notes on genera of the Hysteriales. These notes of his and the views of other workers were summarized, and the results of further study were given, in his discussion "Ueber die Hysteriaceae" (76). Von Hoehnel pointed out that the group had come to be very unnatural. He considered the Hysteriaceae to be

Lophiostomaceae with more or less drawn-out perithecia (hysterothecia) and classified them with the Pyrenomycetes. He believed that these two families form a natural group, for which he proposed the name Hysterostomaceae.

Of the fifty-seven or more genera which had fallen into the Hysteriales, von Hoehnel decided that only ten of them really belong there. He gave a key for these genera, and separated out a new genus (or at least sub-genus) Psiloglonium, for species of Glonium without subiculum.

The disposition von Hoehnel would make of the genera to be removed from the Hysteriales may be indicated as follows:

To the Phacidiales (see also (75)): Schizothyrium, Hypoderma, Hypodermella, Hypodermopsis, Lophodermellina, Nymanomyces, Lophodermium, Lophodermella, Aldona, Colpoma, Hysteriopsis, Sporomega and Synglonium.

To the Ostropaceae (in the Discomycetes); Ostropa and Robergea; he would include these genera in a group with Stictis, Vibrissea, Schizoxylon, etc.

To the Triblidiaceae (formerly placed in the Phacidiales); Pseudographis, Rhytidhysterium, Tryblidiella, Tryblidium, and Delphinella (= Pleodothis and Pleoglonis).

To the Dothideales (see also (74)): Cycloschizon, Dielsiella, Hysterostomella, Mendogia, Parmulariella, Parmularia.

To the Lembosiaceae: Actidium, Aylographum (= Lembosiopsis), Hadotia, Morenoëlla, Lembosia, Lembosiella.

To the Sphaeriaceae: Delpinoëlla, Erikssonia, Graphyllium (= Clathyospora), Merillopeltis, and Schizacrospermum.

To the Patellariaceae: Baggea and Hysteropatella.

To the Cenangiaceae: Angelina.

To the Sordariaceae: Acrospermum.

To the Lichens: Phragmographium.

To be discarded: Aporia.

Table I includes the genera left by von Hoehnel in the Hysteriales, and gives the geographical distribution of the species so far as listed in the various volumes of Saccardo's *Sylloge*. In this table "Asia" includes the adjacent islands. It may be seen that there are a total of one hundred and thirty-two species listed as occurring in Europe, and one hundred and eleven in North America. Saccardo had not, of course, included data from various lists of fungi for different regions; there are for example many more than twelve species common to both Europe and North America. It must also be remembered that several species included by Saccardo have been or will be shown to be only synonyms.

The recent tendency to remove a number of genera from the Hysteriales merely indicates that the order had long remained

without comprehensive and comparative study. It still remains to be seen whether such radical re-adjustment as von Hoehnel proposed best fits a logical arrangement of the Ascomycetes; the intermediate position of the Hysteriales makes their study of high importance.

The scattered references to the parasitism of members of the Hysteriales have not been included in this paper, but it should

Table I. *Distribution of species according to Saccardo.*

	N.A. only	Eur. only	N.A. & Eur.	S.A. only	Asia only	Austral. & N.Z.	Africa only	Miscellaneous	Total
Dichaena	4	1	2	—	—	—	—	—	7
Farlowiella	—	1	1	—	—	—	—	—	2
Gloniella	5	21	—	12	6	2	—	1 doubtful	47
Hysterium	37	24	2	11	8	—	1	1 Eur., Asia and N.A. 1 Eur., S.A. and N.A.	85
Gloniopsis	7	19	1	3	1	2	—	2 doubtful	35
Hysterographium	18	11	5	10	3	—	4	1 N.A., Eur. and Austral. 1 N.A., Eur., Afr. 1 N.A. and Asia	54
Glonium	14	18	—	10	—	2	—	1 N.A. and S.A. 3 Eur. and S.A.	48
Bullardiella	—	1	—	—	—	—	—	—	1
Mytilidion	3	12	—	1	—	—	—	—	16
Ostreion	1	—	—	—	—	—	—	—	1
Lophium	4	5	1	1	—	—	—	—	11
Total	93	113	12	48	18	6	5	12	307

be noted that Tubeuf (77) succeeded in growing *Lophodermium pinastri* in pure culture. Brefeld had previously failed to culture a species of Lophodermium. Tubeuf did not succeed in producing infection on pines by artificial inoculations from his culture.

Summary.

The members of the Hysteriales were at first confused with lichens, certain of which they resemble. Early workers inevitably drew up vague descriptions of these fungi. The name of the group is based on the genus Hysterium, which was first used by Tode. The type species is *H. pulicare*, the name of which can be traced back to Lightfoot. Persoon succeeded in bringing a number of similar forms together, largely by an inclusive interpretation of the genus Hysterium. Chevallier first used the name "Hysterineae" for an order, and he also separated into another order certain genera now included in the Phacidiales. This work has been generally overlooked in considering the beginning of a separate grouping of these fungi. Corda used the family name Hysteriaceae to include also the Phacidiales; most

other workers, down to the middle of the 19th century, including Fries, placed the genera now classified in the Hysteriales with the Phacidiales. The genera came finally to be distinguished principally on the basis of the colour, shape, and septation of spores.

There has always been confusion in the use of names to distinguish orders, sub-orders, families, etc.; indeed, the same name is sometimes used by a writer in two senses: see Corda's arrangement. Several mycologists (Saccardo, Spegazzini, von Hoehnel (76), and others) include all the genera in one family; if von Hoehnel's contentions that Dichaena should be placed in a separate family, and that the Hypodermataceae, Ostropaceae, and Acrospermaceae all belong elsewhere, should be followed, only the family Hysteriaceae is left of those now usually (64, 67, 71) included in the order.

The Hysteriales have been placed in the Pyrenomycetes and Discomycetes about equally commonly, which indicates clearly that they form a transitional group; Rehm (67) compromised by placing them intermediately. Certain genera have likewise undergone a great amount of shuffling; the most conspicuous example being Acrospermum (which Tode (13, p. 8) described as "Fungus simplicissimus"!), which has been placed, as noted herein, in Clavaria, Sclerotiaceae, Tremella, Phacidiales, Hysteriales, Pseudohysterineae, Sordariaceae and recently by Riddle ((78) agreeing with Ellis and Everhart) in the Hypocreales. The most recent tendency is to reduce considerably the number of genera included in the Hysteriales.

Pycnidial stages, attributed to the Hysteriales, have been noted by certain workers (54, 64); these are usually hysterioid in nature, and include Leptostroma and Psilospora.

Many workers not mentioned herein have described species, extended the knowledge of the distribution, or added other data regarding the Hysteriales. It is obvious, however, that the group is still in need of comparative and synthetic study.

LITERATURE.

(1) Ray, John.—Synopsis methodica Stirpium Britannicarum, etc., Ed. III (1724).
(2) Micheli, P. A.—Nova Plantarum genera (1729).
(3) Dillenius, J. J.—Historia Muscorum (1741).
(4) Haller, Albrecht von.—Nomenclator ex Historia Plantarum indigenarum Helvetiae excerptus (1769).
(5) Linnaeus, Carl.—Flora Suecica (1745).
(6) —— Species plantarum (1753).
(7) Lightfoot, John.—Flora Scotica (1777).
(8) Wiggers, Friedrich H.—Primitiae Flora Holsaticae (1780).
(9) Hoffmann, Georg Franz.—Enumeratio Lichenum iconibus et descriptionibus illustrata (1784).
(10) Bulliard, Pierre.—Histoire des Plantes vénéneuses et suspectes de la France (1784).

(11) TODE, HEINRICH JULIUS.—Beschreibung des Knopfschwammes (Acrospermum) eines neuen Schwammgeschlechts. Schrift. Berlin. Ges. Naturf. Freunde, IV, pp. 263, 265 (1783).

(12) —— Beschreibung des Venusschwammes (Hysterium). *Ibid.* V, pp. 53–55 (1784).

(13) —— Fungi Mecklenburgenses selecti, I (1790).

(14) —— *Ibid.* II (1791).

(15) BOLTON, JAMES.—An History of Fungusses growing about Halifax, III (1789).

(16) ACHARIUS, ERIK.—Lichenographiae Suecicae Prodromus (1798).

(17) —— Lichenographia universalis (1810).

(18) —— Synopsis methodica Lichenum (1814).

(19) PERSOON, CHRISTIAN HENDRIK.—Observationes Mycologicae, I (1796).

(20) —— Synopsis methodica Fungorum (1801).

(21) —— Mycologia Europaea (1828).

(22) SOWERBY, JAMES.—Coloured figures of English Fungi or Mushrooms, III (1803).

(23) ALBERTINI, J. B. and SCHWEINITZ, L. D. DE.—Conspectus Fungorum in Lusatiae (1805).

(24) LAMARCK, J. B. P. A. DE M. DE and DE CANDOLLE, A. P.—Flora Française, Ed. 3, II [1815] (1805).

(25) MUEHLENBERG, G. H. E.—Catalogus Plantarum Americae Septentrionalis (1813).

(26) NEES VON ESENBECK, C. G. D.—Ueberblick des Systems der Pilze und Schwämme (1817).

(27) FRIES, ELIAS M.—Systema Mycologicum, II (1823).

(28) —— Systema orbis vegetabilis (1825).

(29) —— Observationes Mycologicae (1815).

(30) —— Elenchus Fungorum (1828).

(31) BRONGNIART, ADOLPHE.—Essai d'une Classification naturelle des Champignons (1825).

(32) GREVILLE, R. K.—Scottish Cryptogamic Flora, III (1825).

(33) CHEVALLIER, F. F.—Essai sur les Hypoxylons Lichenoides. Journ. phys. chim. d'hist. nat. et des arts, XCIV, p. 28 (1822).

(34) —— Flore général des environs de Paris, I (1826).

(35) SCHWEINITZ, L. D. VON.—Synopsis Fungorum Carolinae. Schrift. d. Naturf.-Ges. zu Leipzig, I, pp. 20–131 (1822).

(36) —— Synopsis fungorum in America Boreali. Trans. Amer. Phil. Soc. IV, pp. 141–316 (1834).

(37) DUBY, J. E.—Botanicon Gallicum (1830).

(38) WALLROTH, K. F. W.—Flora Cryptogamica Germaniae, II (1833).

(39) FRIES, E. M.—Epicrisis Systematis Mycologici (1836–38).

(40) —— Corpus Florarum provincialium Sueciae, I. Floram Scanicam (1835).

(41) —— Summa Vegetabilium Scandinaviae, II (1849).

(42) LIBERT, MARIE ANNE.—Précis des observations sur la famille des Hypoxylons. Ann. Sci. Nat., sér. 2, VII, pp. 121–125 (1837).

(43) NEES VON ESENBECK and HENRY, A.—Das System der Pilze (1837).

(44) RABENHORST, G. L.—Deutschlands Kryptogamen-Flora, I (1844).

(45) CORDA, A. C. J.—Icones Fungorum hucusque cognitorum, V (1842).

(46) —— Anleitung zum Studium der Mycologie (1842).

(47) DE NOTARIS, G.—Prime linee di una nuova disposizione de Pirenomiceti Isterini. Giorn. Bot. Ital., II, 2, p. 5 (1847).

(48) LÉVEILLÉ, J. H.—Considérations mycologiques, suivies d'une nouvelle classification des Champignons (1846).

(49) BONORDEN, H. F.—Handbuch der allgemeinen Mykologie (1851).

(50) BERKELEY, M. J.—Introduction to cryptogamic Botany (1857).

(51) —— Outlines of British Fungology (1860).

(52) DUBY, J. E.—Mémoire sur la tribu des Hystérinées de la famille des Hypoxylées (Pyrénomycètes). Mem. Soc. Phys. Hist. Nat. Genève, XVI, pp. 15–70 (1862).

(53) TULASNE, L. R. and C.—Selecta Fungorum Carpologia (1861–5).
(54) TULASNE, L. R.—Nouvelles recherches sur l'appareil reproducteur des champignons. Compt. rend., XXXV, p. 841 (1852).
(55) DE BARY, A.—Comparative morphology and biology of the fungi, mycetozoa, and bacteria. English translation (1887).
(56) FUCKEL, L.—Symbolae mycologicae. Jahrb. Nassau. Ver. Naturk., XXIII u. XXIV (1869–70).
(57) COOKE, M. C.—Handbook of British Fungi (1871).
(58) —— Synopsis of the Discomycetous Fungi of the United States. Bull. Buffalo Soc. Nat. Sci. (1875).
(59) SACCARDO, P. A.—Mycologiae Venetae Specimen. Atti Soc. Venet.-Trent. Sc. Nat., II, pp. 155–160 (1873).
(60) —— Conspectus generum pyrenomycetum italicorum. Atti Soc. Venet.-Trent. Sc. Nat., IV, pp. 77–100 (1874).
(61) SPEGAZZINI, C.—Fungi Argentini. I. Anal. Soc. Cient. Argentina, IX, pp. 158–192 (1880).
(62) —— Fungi Guaranitici. I. Anal. Soc. Cient. Argentina, XVI (1883).
(63) GILLET, C. C.—Champignons de France. Les Discomycètes, I (1879).
(64) ELLIS, J. B. and EVERHART, B. M.—The North American Pyrenomycetes (1892).
(65) ENGLER, A. and PRANTL, K.—Die natürlichen Pflanzenfamilien, I, I (1897).
(66) REHM, H.—Revision der Hysteriaceen im herb. Duby. Hedw., XXV, pp. 137, 173 (1886).
(67) —— Ascomyceten: Hysteriaceen und Discomyceten. *In* Rabenhorst: Die Pilze Deutschlands, Oesterreichs, und der Schweiz (1896).
(68) —— Beiträge zur Pilzflora von Südamerika. V. Hysteriaceae. Hedw., XXXVII, pp. 296–302 (1898).
(69) —— Revision der Gattungen Tryblidiella Sacc., Rhydithysterium Speg., Tryblidaria Sacc., Tryblidium Rebent., Tryblidiopsis Karst. Ann. Myc., II, pp. 522–526 (1904).
(70) BOUDIER, E.—Histoire et classification des Discomycètes d'Europe (1907).
(71) SCHROETER, L., *in* COHN, F.—Kryptogamen Flora von Schlesien (1908).
(72) SEAVER, F. J.—Discomycetes of North Dakota. Mycol., I, pp. 104–114 (1909).
(73) CLEMENTS, F. E.—The genera of fungi (1909).
(74) THEISSEN, F. und SYDOW, H.—Die Dothideales. Ann. Myc., XIII, pp. 149–746 (1915).
(75) HOEHNEL, FR. VON.—System der Phacidiales. Ber. Deut. Bot. Ges., XXXV, pp. 416–422 (1917).
(76) —— Mycologische Fragmente. Ann. Myc., XVI, pp. 145–154 (1918).
(77) TUBEUF, C. VON.—Kultur parasitischer Hysteriaceen. Naturw. Zeits. Land-Forstwirts., VIII, pp. 408–411 (1910).
(78) RIDDLE, L. W.—Observations on the genus Acrospermum. Mycol., XII, pp. 175–181 (1920).

NOTE.

A DIE-BACK IN SUSSEX.

Boughs of apple, Winter Pearmain and Lane's Prince Albert, affected with a bark disease have been forwarded to the Ministry by Mr John Goaman, one of the Ministry of Agriculture's Inspectors from the south-western, or Chichester, district of Sussex. This disease was considered by the growers to be causing a die-back and the trees have been cut back and the affected boughs burnt. The fungus present was in a pycnidial stage, the pycnidia globose, depressed, with a thick wall and set in a purplish mycelium, and with large hyaline spores of a Macrophoma type.

The fungus corresponds with New Zealand specimens of *Diplodia Griffoni* Sacc. & Trav.

Diplodia Griffoni Sacc. & Trav. Sacc. Syll. xx, p. 1228 (1911) and XXII, p. 994 (1913).

Pycnidia parasitic, somewhat large, scattered or grouped, simple, or divided into loculi; spores for a long time hyaline, thick walled, elliptic oblong, somewhat irregular, with granular contents 20–30 $\mu \times$ 10–13 μ becoming ovoid and ellipsoid, uniseptate, 22–25 $\mu \times$ 10–14 μ, fuliginous and quite smooth.

This fungus disease was first described from France (Diplodia sp. Griffon et Maublanc, Bull. Soc. Myc. France, 1910, p. 314, T. xiii et T. xiv) and occurs also in New Zealand as a bark parasite on apples. I am indebted to Mr Grove and Miss Wakefield for their assistance in identification.

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WILLIAM BERIAH ALLEN.

(1875—1922.)

By Carleton Rea.

William Beriah Allen was born at Benthall, Shropshire, in 1875. He was the only son of William Allen and Julia Caroline (née Lopez) and was educated at Ellesmere College, subsequently proceeding to Hertford College, Oxford. Unfortunately his father required his assistance in business and his career at the University was determined before he had completed the full number of terms, but doubtless if he had he would have graduated with high honours. His father was a potter by profession and after his death the son carried on the Benthall Pottery works and also developed a very prosperous foreign china and glass trade. Brought up in the beautiful country surrounding his home Allen in early life took a great interest in natural history and soon acquired a fair knowledge of the plants and birds of the district. He was afterwards attracted by the fungi, and it was as a student of these that I first made his acquaintance at the Hereford foray of the British Mycological Society in 1902. He had been advised by the well-known Shropshire mycologist, William Phillips, to attend this meeting but it is a somewhat curious fact that Phillips really tried to dissuade him from mycology. From this time onwards it was my privilege to rank him as one of my best and dearest of friends, and together we enjoyed many forays in search of our beloved fungi. Allen was more especially interested in the Basidiomycetae, Discomycetae and Mycetozoa and in all of these groups he made some very interesting discoveries and additions to the British Flora. He was a keen collector, quick to detect minute differences and well acquainted with the works of Fries, Quélet and Lister. Monsieur René Maire named *Omphalia Allenii* in his honour at the Baslow foray in 1909, and Miss A. Lorrain Smith dedicated *Cudoniella Allenii* to him from specimens gathered in Shropshire in the spring of 1907. In 1909 he described in our *Transactions*, vol. III, p. 92, the beautiful little violet Clavaria aptly named by him *Clavaria conchyliata* but which had been previously recorded by Saccardo under the uncouth name of *Clavaria Bizzozeriana*. He also found in my company the first British specimens of *Glischroderma cinctum* (Fuck.) Rea in Wyre Forest in 1909, of *Inocybe squarrosa* Rea near Worcester in 1915, of *Lycoperdon velatum* Vitt. at Aldenham, Shropshire in 1902, and of many others too

numerous to set out in a brief obituary notice. Allen was a very busy man and his engagements prevented him from attending many of the annual forays of our Society, and although on several occasions he was approached with a view to allowing his name to be proposed for the position of President of this Society we shall now deplore the fact that such an eminent mycologist was never elected to that position. He passed quietly away on the 20th of November, 1922, at the early age of forty-seven and was laid to rest in the pretty churchyard at Benthall three days afterwards, when it was my privilege to attend his funeral and pay my last tribute of respect and affection on behalf of the British Mycological Society and myself. All our members will deplore the loss to science and our society in particular by the death of such an able and distinguished mycologist and tender their heartfelt sympathy to his sorrowing widow.

RECENT WORKS ON LICHENS.

By A. Lorrain Smith, F.L.S.

In the following pages, a summary is given of publications that were unavoidably omitted from the handbook "Lichens," and that have appeared since the manuscript was handed to the press in the beginning of 1920. During the war-years and for some time after, it was difficult or impossible to get hold of the works of continental botanists. A different apology is due in the case of Sernander's ecological works: in that case it was the language difficulty that barred the way at the time.

Two valuable papers dealing with recent literature appeared in 1921: one by Bioret which reviews lichenological work from 1910 to 1919; and one by Paulson which is a résumé of British Lichenology from 1911 to 1920.

In this survey purely systematic publications have not been included: these are both numerous and varied; the essential work of knowing and classifying the plants has not been neglected. It may, however, be permitted to direct attention to Bernt Lynge's (1921) Studies of Norwegian Lichens, full of helpful notes, to the Handbook of British Lichens by A. Lorrain Smith (1921) which provides a key based on the Monograph of British Lichens, and to W. Watson's Determination of Lichens in the Field (1922), a key to the genera and to many species of common British lichens based on field characters and intended to be of service to field botanists especially in their study of ecology.

LICHEN GONIDIA.

Several writers have dealt with the types of gonidia present in the lichen thallus, and with their behaviour in culture media. Letellier (1917), a pupil of Chodat, has devoted himself especially to this research. He isolated a *Nostoc* from *Peltigera* sp., and in culture he found that nitrates and ammonium salts were utilized by the alga but not peptone or glycocol. Glucose and sugars generally favoured growth, a result opposite to that obtained by Chodat and others with free Cyanophyceae. Eva Mameli (1920) in her chemical study of the blue-green lichens decided that in the lichen thallus the algal constituents suffered no important change except occasionally in the size of the cells. Linkola (1920) has cultivated *Nostoc* gonidia from eight different species of *Peltigera*: they grew well and formed hormogonia which developed into spores or into *Nostoc* colonies. Linkola refers them all to *Nostoc punctiforme* Hariot. The only variation

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of importance occurred in the gonidia of *Peltigera malacea*, and that he thinks may indicate some specific difference or only some particular physiological race.

Waren (1920), a pupil of Elfving, has chiefly been occupied with bright-green gonidia which he cultivated from twenty-one different species of lichens. He tested them on different nitrogenous media and found that they grew most freely on amino-acids. He classifies the gonidia of most of our common lichens under the genus *Cystococcus* which he divides into two sections, *Eucystococcus*, in which there is vegetative division (*Protococcus*), and *Eleuterococcus*, the species of which apparently form autospores in the cultures. The gonidia from the different species show differences of form and colour in the culture colonies which leads him to think that each lichen species has its own particular gonidium. Bioret (1921) however thinks that in organisms so polymorphic as green algae it is impossible to determine aberrations as specific or even racial. Waren found that the gonidia in *Xanthoria parietina* from Finland differed from those of the species collected in Holland.

Waren's views on the gonidium do not accord with those of Paulson (1921) published in last year's Transactions of this Society. The latter dealt with the living thallus and found in a very large number of lichens the same type of sporulating gonidium present which he refers to *Chlorella* sp.

SYMBIOSIS OR PARASITISM.

The nature of the association between the two organisms in the lichen thallus is still under discussion. Paulson (1921) maintains the necessity of regarding both organisms living in a healthy condition as symbiosis, as neither succumbs to the other. The alga is not parasitized; it sporulates abundantly at certain seasons and any dead members are due to the natural process of decay. Eva Mameli (1920, 4) has arrived at the same conclusion as a result of her study of the thallus. She found occasional dead algae but these were chiefly in the deeper layers where light is scanty, and in purely algal colonies such dead members are equally present. The possibility of the fungal haustoria piercing the algal cell is not ruled out, but it happens so rarely, that it is impossible to regard parasitism as a necessary condition. Bachmann (1922) in further work on calcareous endolithic lichens finds in nearly all of those examined that the gonidia, *Scytonema* or *Trentepohlia*, live side by side with the hyphae. The *Scytonema* filaments (in *Petractis clausa*) are surrounded by small-celled hyphae which are in contact but never penetrate. Certain free filaments travel deeply into the rock, and there die off more quickly than those closely associated with hyphae.

In the lime lichens associated with *Trentepohlia* there is also contact without penetration, and free wandering gonidia are frequent; in those associated with *Protococcaceae* there is a well-marked zone of gonidia and in certain species occur wandering members unconnected with hyphae.

He found, however, true parasitism in the thallus of *Arthopyrenia tichothecioides*: the gonidia (*Gloeocapsa* sect. *Xanthocapsa*) form a poorly developed layer towards the surface of the thallus; no wanderers occur in the deeper tissue. The hyphae form a circle round the algal cells which is never quite complete; the swollen ends of the hyphae act as haustoria and destroy some of the algae. This unusual and peculiar habit of growth has induced him to place the species in a new genus, *Xanthopyrenia*. It may also be noted that a blue-green gonidium in *Arthopyrenia* is exceptional.

Bioret (1921) also noted a case of parasitism in the thallus of *Opegrapha herpetica* which has very large gonidial cells (*Trentepohlia*). In several instances he observed penetration of these gonidia by haustoria of the hyphae—the only instances recorded of parasitism in Graphidaceae. Bioret evidently found parasitized gonidia in only one individual of the species.

An undoubted case of parasitism is brought forward by Goebel (1915). He describes a species of *Ephebe* from an aqueous habitat in Brazil. The alga—*Stigonema*—was destroyed by the penetrating haustoria of the fungus hyphae, more particularly in the centre of the thallus. The gonidia towards the periphery were less seriously attacked, and those at the growing tips were practically undamaged. This parasitic condition is not characteristic of our native Ephebes which inhabit a more or less dry substratum.

McWhorter (1921) adduces as proof of the parasitic nature of lichens—or more particularly of lichen hyphae—the cases he has observed in which mosses are destroyed by lichens—*Cladoniae, Physciae, Amphiloma* etc. The destruction was partly due to parasitism and partly to smothering. He thus finds confirmed Bruce Fink's definition: "a lichen is a fungus which lives during all or part of its life in parasitic relation with an algal host and also sustains a relation with an organic or inorganic substratum." His work however proves nothing in regard to the algal host, though the relation to the organic substratum is evidently that of a marauder.

M. and Madame Moreau (1921) have their own views as to the problem of symbiosis: they look on the lichen—the fungal part—as a gall-structure due to the exciting action of the alga. They have studied the occurrence of cephalodia in *Solorina* and find in their structure new proof of the gall-theory. All the

species of *Solorina* contain cephalodia; that is an associated alga other than the normal gonidium. The intruding alga *Nostoc* sp. often becomes surrounded by the *Solorina* hyphae and a tubercle or cephalodium is formed which is referred to by the Moreaus as undoubted gall-structure.

We understand by gall-structure an abnormal development of the plant affected, and due to the irritation of insect or fungus. It is as far as we know a purely vegetative development which never bears fruit, though the parasite causing the gall reproduces freely. In the lichen thallus each symbiont fruits after its kind, and the fungus—the gall plant according to the Moreaus—fails to develop at all without the alga.

A very curious instance of symbiosis between two fungi is described by Vainio (1921) as *Mycosymbiosis*. The association was discovered on the leaves of a tree from the Philippines. The first fungus to arrive, *Gonidiomyces sociabilis* gen. and sp. nov., somewhat resembles a *Capnodium*: it has stoutish branching septate mycelium of a dark brown colour: no fruits were found on it though presumably it is a member of the Pyrenomycetes. The second fungus, *Diplothrix mirabilis*, also new to science, has a fine gray mycelium. It lives on the hyphae of *Gonidiomyces* encircling them and finally producing *Peziza*-like apothecia. Neither fungus suffers from the association, though possibly *Diplothrix* gains most. The resultant growth resembles in form the lichen *Strigula*, also an epiphyte on leaves.

MORPHOLOGY.

A number of workers have selected certain groups and genera for detailed examination. Zanfrognini (1917) in a paper on the lichens of Somalia has added to the systematic description of the lichens an account of the structure of cortex and medulla in several species of *Ramalina* and *Usnea*. Shirley (1919) also approaches systematy by way of histological research. He has given much attention to the families Parmeliaceae and Stictaceae, studying cortices, rhizoids and more especially the pores that he finds present in the thalli; these latter occur in abundance, he finds, all over the thallus of *P. tiliacea*, minute openings difficult to see. In *Parmelia limbata* he has traced the pores or channels from just above the rhizoids to the upper surface where they show as shallow closed pits. He holds that these pores along with the cyphellae and other openings in the thallus of Stictaceae are not only for service in aeration, but allow water and food to be absorbed into the tissues. Shirley forgets the ready absorption of water by the thalline cortex, which water may or may not be charged with mineral salts. Relying on his interpretation of these structures, he would unite under Par-

meliaceae as Section 1: *Parmelia, Sticta* (comprising also *Lobaria* and *Ricasolia*) and *Stictina*, and as Section 2: *Physcia, Anaptychia* and *Anzia*. Why *Anzia* is placed along with *Physcia* he does not explain.

Moreau (1921) also attacks the problem of classification according to thalline form in Stictaceae. He has examined the thallus of seven different species of *Sticta, Stictina, Lobaria, Lobarina* and *Ricasolia* and would unite all these genera under *Sticta*. He finds in the development of the cephalodia a new proof of the phenomenon of biomorphogenesis, that is, in his view, the parasitism of the alga on the fungus, or a symbiosis that excites the fungus to unnatural growth.

A curious morphological development is noted by Zahlbruckner (1921); he records an upright branching *Caloplaca* from S.W. Africa: it had the outward form of *Teloschistes*, but without a cortical layer. Bouly de Lesdain (1921) describes a new genus of Pyrenolichens *Henrica* with rosulate thallus from which podetia-like structures are produced. The plant was found by Abbé Henry on schistose rocks in Italy.

There have been published elaborate papers by Bachmann (1918 and 1922) which continue his work on endolithic lichens. He takes up calcicolous forms associated with *Trentepohlia, Xanthocapsa* and *Scytonema* (see also p. 194). Among the principal points in the paper, we note the description of an epinecral layer of dead hyphae and gonidia over the surface of the thallus of a number of species and above that layer in certain species a cap of slender living hyphae. He found also in the deeper layers of some species clumps of hyphae which he designates as "tubercles." There is great variation in respect of the position of the gonidial zone, but in most thalli solitary algal filaments penetrate more or less deeply into the rock unattached to hyphae. In other species similar filaments protrude from the surface of the thallus and live in the open. In most of the species associated with *Trentepohlia* oil-bearing hyphae or sphaeroid cells were present.

Other forms of embedded lichens have been investigated by E. J. Fry (1922) in connection with the study of the pioneer cryptogamic vegetation of the limestones of Great Orme and S.E. Anglesea. She immersed chips of the rock in acid until the limestone was thoroughly dissolved; the thallus was then washed and prepared for microtome sections. She notes the differences in the cortical zone, the spacing of gonidia and hyphae, the character of the rhizoidal hyphae and above all the occurrence and form of oil cells (see p. 199). They were present in all the lichens examined (*Verrucaria calciseda, Lecidea immersa, Placodium rupestre* var. *calvum* f. *incrustans, Aspicilia calcarea* and

two others indeterminable) as swollen tips of the hyphae, as clusters of sphaeroid cells, as solitary inflated filaments or in strands of hyphae. These oil cells were more abundant in the quicker growing species and in regions of special growth.

In his paper on Graphidaceae, Bioret (1921) finds that the elliptic contour of the thallus in numerous species depends on the form of the bark cells of the host tree, as these elongate transversely so does the thallus of the lichen. The thallus varies considerably in the different genera and species, according to the bark substratum on or within which they subsist. Heredity is manifested mainly in the character of the lirellae.

CYTOLOGY.

There is little to add to our knowledge of cytology. Moreau (1921) in his examination of Stictaceae found that the ascogonium was a complex of uninucleate cells. Trichogynes were formed and reached the surface of the thallus, but degenerated without any copulation with spermatia. The ascogonium itself may become a plectenchyma; the asci and the paraphyses arise from the ascogonial cells.

Bioret (1921) notes in his account of the asci and spores of Graphidaceae that the length of the spores is proportional to the length of the asci which in turn are proportioned by the depth of the apothecia. The spores in several genera are distinguished by transverse septation into a varying number of cells; in those of the type of *Graphis dendritica* there are six or seven septa, division taking place first at the centre. After the first division, a second takes place in each cell close to the median septum, the inner cell does not divide again, but the process is repeated in the terminal cells. The outermost cell alone retaining the power of septation. He also notes that in Graphidaceae as in many other lichens the fruit continues to form asci and spores for many years, though he does not find that sporulation is continuous. The cell division in polarilocular spores is discussed by Mameli (1920, 3). She found in *Caloplaca aurantiaca* var. *polycarpa* many spores distinctly divided by a septum, and the septum was evident along with the channel of union between the polar cells; in other spores the channel tended to disappear. It is satisfactory to note the confirmation of septation in these spores. She also draws attention to the reaction of the apothecial tissues with potash: the tips of the paraphyses and in some cases the contents of the spore alone are stained crimson.

PHYSIOLOGY.

A study of nutritive salts in the lichen thallus was made by Salomon (1914) and of the exchange of substances between algae

and hyphae. He tested over 100 species from various groups and has determined in them inorganic salts of phosphorus, magnesium, calcium, and nitrogen (ammonium salts with nitrites and nitrates). The first four were found in both symbionts; nitrites and nitrates were difficult to locate and are probably used up as soon as they are formed; phosphorus was more abundant in the hyphae than in the gonidia; phosphoric salts as small granules, and crystals of magnesium were found in the apothecia, or more rarely in the thallus.

Mameli (1920, 1) tested for the presence of starch in lichens, and found it—as we should expect—in or close to the gonidia. Starch is a constituent of the green cells alone and can hardly be considered as a product of the symbiotic plant. Glycogen (1920, 5) she found in the gelatinous substance of the cyanophyaceous algae, it also is the product of one symbiont (see West's "Algae," p. 14). Amyloid determined by Moreau in the hymenial tissues has been proved by her to be an insoluble substance.

Bioret (1921) noted in the apothecia of *Graphis* sp. large quantities of minute refractive bodies distributed through the hymenial tissues. He concluded finally that these were oil-drops, and suggests that their function may be to preserve the hymenium from excessive desiccation.

E. J. Fry (1922) discusses the significance of oil in limestone endolithic lichens. She concludes that: "there is probably some relation between growth, evolution of carbon dioxide, oil formation, and solution of the limestone." She agrees with other workers that the oil is not a storage of reserve food but is waste material produced under adverse conditions during the evolution of carbon dioxide. She finds further that the boring action of the lichens is brought about by the carbon dioxide of respiration dissolved in water.

Ethel Mellor (1921 and 1922) has described the action of lichens on glass, and finds as did Gaston Buchet that they may seriously damage church windows. She has identified from the windows 22 lichens, one of which with its variety (*Caloplaca vitricola* and var. *violacea*) is new to science. The conclusions she comes to are:—The immediate cause of corrosion of the glass is the mechanical action of the lichens on glass which has already been chemically altered by moisture, glass having an affinity for humidity in which carbon dioxide from the air is dissolved; the silicates become more or less hydrolysed, with formation of silicic acid and hydrates of calcium and sodium; the lichen hastens the alteration that had already commenced, burrowing into the glass and excavating small flakes. The glass coloured yellow resists corrosion a long time.

Bachmann (1922) has published a paper on the physiological aspects of the lichen thallus immersed in limestone. He considers that water supply is the chief advantage gained by the plant. He tested the rate of absorption for limestone containing—or free from—lichens, and he found that limestone harbouring lichens had a greater capacity of absorption and retained the moisture longer than the lichen-free rock.

Comparing lime lichens with each other he found that those associated with *Pleurococcus* gonidia showed less capacity of water absorption than those with *Trentepohlia*. In the latter case the stone is more deeply pierced by the wandering filaments of the alga. He contrasted silicicolous lichens with calcicolous and found that the latter had the greater capacity of absorption.

Considerable use is made of reagents by systematic workers, notably by Zanfrognini (1917) in his work on Somali lichens. Bachmann (1922) found methyl-green in acetic acid of value as a colour reagent: it stained the hyphae of fungi parasitic on lichens, while the lichen hyphae themselves were unaffected. It would be interesting to see the test applied to the group of half-lichens that are mid-way between lichens and fungal parasites.

During the war, there arose in all countries the necessity to utilize every kind of food supply. Hesse (1915), well known for his researches on the chemistry of lichens, turned his attention to their economic properties. He worked out a comparison of their sugar content with that of potatoes and found that for *Cetraria islandica* the proportion was 1 : 3·35; for *Cladonia rangiferina*, the reindeer-moss, 1 : 2·5. Both of these lichens therefore might be used with advantage as food for man, if the acid products were eliminated. Jacobj (1916) in a pamphlet also encouraged the use of lichens as food stuffs. He mixed reindeer-moss with the food of young pigs with the result that the animals throve better than with ordinary food alone. Rabbits and hares were fed with *Evernia prunastri* after extraction of the acids and the results were also satisfactory.

Bernt Lynge (1921) draws attention to the value of *Cetraria islandica* as a food supply and to *Cladonia alpestris* as a fodder plant; as such the latter is largely employed by farmers in countries bordering on arctic regions.

BIONOMICS.

Under bionomics we touch on many sides of lichen development. Sántha (1916) tested sections of lichens of the genus *Physcia* with polarized light. In most species the upper cortex was clear, the other tissues were more variable as regards the transmission of light and in one group which he designates

obscure the sections were wholly dark. The differences were so constant as to be of specific importance.

Nienburg (1919) has attacked the debated subject of the rate of lichen increase in size. He watched lichen sporlings in nature for a number of years and found that light was more favourable to growth than shade, which suggests that the hyphae respond to increase of gonidia. Taking *Parmelia furfuracea* he figures after one year's growth minute lobes which in three years had reached a length of 1·75 mm. in the shade and about 7·25 mm. in full light. Finally after eight years the maximum size attained was about 22 mm. × 35 mm. These observations agree fairly well with the rate of growth previously observed in foliose lichens, though some other types of lichens increase at a more rapid rate. During the same research he also established definitely that lichens are phototropic: that they grow towards the light and even manage to orient their surfaces so as to gain the fullest amount of sunlight though in this respect lichens are not all equally affected.

Strato (1921) made a series of observations on growth and regeneration in the thallus of *Peltigera canina*, and he comments also on the importance of light. As light is a necessity for the life of the gonidia, so it is one of the essentials of thallus regeneration. Growth in the thallus of *Peltigera* takes place at the circumference; isidia as outgrowths from the thallus are in respect of increase terminal bodies: when the thallus is injured isidia are frequently formed, being induced by the urgent growth of the algae. The cortex of the thallus is covered with felted hair and is not able alone to initiate new growth. Moisture as well as light is an essential of growth and the portions of the thallus under experiment would not "regenerate" under a moist bell glass unless on a substratum of earth or moist clay.

Tobler (1921) draws attention to the few lichens now found growing in the Wolbeck Zoological Garden in Westphalia compared with the large number that were recorded (1856–85). He suggests as a reason for the decrease that lichens are very sensitive to change of environment, and chief among the changes that have taken place is the increase of moisture to a degree unfavourable to their growth. The trees in the enclosure have increased, some of them have been felled, and the lichens meanwhile have decreased.

ECOLOGY.

A number of important papers have appeared on some aspect or other of lichen habitats and lichen ecology. One of the most interesting of these is on "Nitrophilous Lichens" by Sernander (1912). The influence on certain lichens of an abundant supply of nitrogen has long been recognized, but Sernander is the first

to have put the matter to the proof. He recognizes two types of such lichens: (1) ornithocoprophilous and (2) coniophilous. The first mentioned lichens occur on rocks by the sea frequented by birds. A sketch is given of the succession of vegetation. On the summit and on the more level parts of the rocks the alga, *Prasiola*, appears first, followed by lichens such as *Rhizocarpon* spp. To *Rhizocarpon* succeed *Lecanora cinerea* and *Parmelia saxatilis*, the *cinerea-saxatilis* formation largely usurping the place of previous growths. The steep rock-faces are occupied by *Parmelia fuliginosa* and the base by *Bacidia inundata*.

If the rocks are frequented by birds the *cinerea-saxatilis* formation is accompanied or replaced by a *Lecanora saxicola* formation, feebly coprophilous, and by *Physcia stellaris* var. *ascendens*, strongly coprophilous, these two formations including also species of *Caloplaca* (*Placodium*) (*vitellina*, *cerina*, *ferruginea*), and by a third formation, *Ramalina polymorpha-Xanthoria lychnea* also strongly coprophilous, on more strongly wind-swept areas than the others. To test these lichens Sernander watered them every evening for a month with a concentrated solution of crow excreta. At the end of the time most of the *Parmeliae*, *Lecanorae* etc. were unhealthy or dead, while *Lecanora saxicola*, *Caloplaca* spp. and *Xanthoria* spp. were in good condition.

Comparing tree lichens with those, he found that on frequented roads, where dung laden dust was abundant, the lichens that flourished best were *Physcia ascendens*, *Ph. ciliaris*, *Xanthoria lychnea* and *X. parietina*, which he classifies as "coniophilous" species. He gives a further list of those he considers as hemi-nitrophilous.

Nienburg (1919) confirms Sernander's results, he adds *Ramalina fraxinea* as also coniophilous. He found nitrophilous lichens on trees that have wounds on the trunk in which ammoniacal substances are developed, and these when diluted by rain stream down the trunk killing all the lichens in their course except the nitrophilous species. Galløe (1920), in his account of Iceland lichens, rather objects to "nitrophilous," "halophilous" etc. as names for associations owing to the difficulty of determining the dividing line, all lichens being, he says, nitrophilous to some degree. Galløe prefers for associations the terms crustaceous, foliose, and fruticose, with formations named after the dominant forms. Tree lichens were rare in Iceland, rock lichens abundant.

Savicz (1913) in a paper on the lichens of Pskov gives a description of turf moors on which he recognizes three lichen formations: (1) a *Sphagnum* formation with *Cladonia rangiferina*, *Cl. sylvatica* and *Cl. alpestris* (these compete with the *Sphagnum* and grow to large dimensions); (2) a shrub formation with

Parmelia ambigua, Cetraria saepincola etc. and (3) finally a tree formation (pines) with *Parmeliae, Everniae, Usneae* etc. and with *Lecanora coilocarpa* on all the small branches.

There is still another paper from these northern climes: Du Rietz (1921) has published an important contribution to general ecology with a special section on lichens. He makes much use of the term "constant." In order to determine the "constants" of any given associations, these were divided up into areas, and the plants determined for each area. Only a limited number of species appeared in each area, but as a result of the tabulation it was found that each association presented a characteristic basis of "constants" or dominant species. On these lines he describes various associations either of mixed vegetation such as the *Pinus silvestris-Calluna vulgaris*-Lichen ass. in which *Cladonia rangiferina* and *Cl. sylvatica* are constants, the former being the dominant species; or again a *licheno-nanolignosa* or *Empetrum nigrum-Stereocaulon paschale* association with *Stereocaulon* as a constant. Other associations include only lichens or lichens and mosses, as for instance a *Parmelia omphalodes* ass. which consists of two mosses and about sixty different lichens, widely represented on Scandinavian sea-coasts on the vertical faces of the rocks. It is impossible to do more than indicate the character of Du Rietz's work; the results are given in tabulated form with the numbers and percentages of the species in the different associations.

Going to more distant lands we learn from Shirley (1919) that in Australia *Parmeliae* inhabit stones, rocks, fences and trees in situations where there are strong contrasts of temperature and rainfall: Also that *Stictae*, so abundant in the southern hemisphere, are to be found in scrubs and on bushes where shade and rain are plentiful.

Plitt (1921), after collecting in Jamaica, concludes that "lichens are rather the children of light than the children of moisture; they are found on the dry barren hillsides, in the intensest sunlight, but rarely in the deeper shadow of the moist jungles." The competition for place between the different forms of vegetation is very keen, but lichens, he found, held their own in the struggle. Plitt very definitely indicates associations as for instance in his account of those that favour special trees: on a rose-bush he found *Usnea florida, U. hirta, Lecanora varia, L. subfusca, Ramalina* sp., *Parmelia* sp., *Lecidea* sp., *Graphis* sp., *Pertusaria* sp., *Collema* sp. and *Haematomma puniceum*. He found marked differences between the lichens on Junipers and those on *Cryptomeria* and he notes that though bamboos were singularly free from lichens, yet on nearly all of them grew *Opegrapha filicina*.

ORIGIN AND DEVELOPMENT.

A brief account of Dr Church's views on the origin of lichens from skinned sea-weeds was given in an Appendix to Lichens (1921). Since then several other weighty papers packed with facts and with reasoning have appeared: it is not possible to do more than indicate the trend of his argument. He thus summarizes the stages from stranded alga to heterotrophic fungus-lichens.

"(1) The alga accustomed to a moving aqueous environment finds itself in standing pools of sea-water, and the failure of oxygen-supply is the most readily conceivable cause of the death of the autotropic surface tissues thus leaving the thallus penetrable (a skinned alga).

(2) Competition for substratum gave the mantle of green intrusive gonidia of the type of *Chlorella*.

(3) The associated plants in subsaturated air obtained more oxygen and grew more freely.

(4) The nitrogen-problem still keeps the plants impoverished.

(5) The water-problem tends to keep them small and restricted to short seasonal periods, thus further delaying the rate of growth."

Again: "Lichens of to-day constitute one of the pioneer races of the older world, on the first rock-surfaces exposed above the retreating sea; and they have held their station to the present time, since no other plant organism can compete with them in endurance on such a feeble food-supply."

In the lichen life-cycle, he traces the parallel history of the origin of the mechanisms of the reproductive organization which are always considered to represent racial continuity. He finds that spermatogamy (fertilization by a sperm or spermatium), now vague for the Ascomycetes as a whole, is undoubtedly the dominant method for Lichen-Fungi, as it is also a biological process for securing cross-fertilization, and is undoubtedly of strictly marine origin. Church contrasts this with the still operative fertilization of the Rhodophyceae. He considers fungi and lichens as relics of a very old race and that "in Ascomycetes, lichen fungi and Laboulbeniaceae may be traced such suggestion of Pre-Floridean or Para-Phaeophycean phyla." "It is the quiet pool that is now the characteristic habitat of Florideae and all spermatogamic races must have passed through the same environment."

These few quotations give merely the barest outline. There is much with which one is in agreement, but much also that one does not accept. For instance he considers the Floridean carpospore as homologous with the ascospore as both are produced in closed bodies. There we entirely disagree, and

there are other statements that seem to us wide of the mark, but his view has to be considered by all future lichenologists and I may also add by mycologists, as he traces the origin of all fungi to stranded and skinned algae.

BIBLIOGRAPHY.

BACHMANN, E.—Neue Flechtengebilde. Ber. Deutsch. Bot. Ges. XXXVI, pp. 150–156, 1 pl. (1918).

—— Der Thallus der Kalkflechten mit Chroolepus-Scytonema- und Xanthocapsa-Gonidien. Nova Acta Ver. Kais. Leop. Carol. Deutsch. Akad. Naturf. Halle, CV, pp. 1–80, 4 pls. (1919).

—— Wie verhalten sich Holz- und Rindenflechten beim Uebergang auf Kalk. Ber. Deutsch. Bot. Ges. XXXVI, pp. 528–39, 12 figs. (1919).

—— Physiology of Crustaceous Lichens. Zeitsch. Bot. XIV, pp. 193–233 (1922).

BIORET, G.—Revue des Travaux parus sur les Lichens. Rev. Gén. Bot. XXXIII, p. 63 et passim (1921).

—— Les Graphidées corticoles. Ann. Sci. Nat. Sér. 10, IV, pp. 1–71, 11 pls. (1921).

CHURCH, A. H.—The Lichen as Transmigrant and The Lichen Life-Cycle. Journ. Bot. LIX, pp. 7–46, 139–45, 164–70, 197–202, 216–21 (1921).

FRY, E. JENNIE.—Some Types of Endolithic Limestone Lichens. Ann. Bot. XXXVI, pp. 541–62, 1 pl., 9 figs. (1922).

GALLØE, OLAF.—Lichen Flora and Lichen Vegetation of Iceland. The Botany of Iceland, II, Part I, pp. 106–248 (1920).

GOEBEL, K.—Eine brasilianische Ephebaceae. Flora, CVIII, pp. 311–15, 2 figs. (1915).

HESSE, O.—Beiträge zur Kenntnis der Flechten und ihrer charakteristischen Bestandteile. Journ. Prakt. Chemie, XCIII, pp. 254–70 (1915). (See also Ann. Mycol. XIV, p. 480, 1916.)

JACOBJ, C.—Weitere Beiträge zur Verwertung der Flechten. Tübingen, I, C. B. Mohr, 8°, 26 pp., 2 pls. (See also Ann. Mycol. XIV, p. 480, 1916.)

LESDAIN, BOULY DE.—Notes lichénologiques. Bull. Soc. Bot. France, LXVIII, pp. 203–7 (1921).

LETELLIER, A.—Étude de quelques gonidies de Lichens. Thèse Univ. de Genève. Inst. de Bot. Sér. 8, fasc. 7, 47 pp., 1 pl. (1917). (See BIORET (1921) Rev. Gén. Bot. XXXIII, p. 156.)

LETTAU, G.—Beiträge zur Lichenographie von Thüringen. Hedwigia, LXI, pp. 97–175 (1919).

LINKOLA, K.—Kulturen mit Nostoc-Gonidien der Peltigera-Arten. Ann. Soc. Zool.-Bot. Fenn. Vanamo, I, pp. 1–23, 1 pl., 7 figs. (1920). (See also Hedwigia, LXIII, Beibl., pp. 105–6, 1922.)

LYNGE, BERNT.—Studies of the Lichen Flora of Norway. Vidensk. Skrift. I, Math. Nat. Kl. n. 7 (1921).

McWHORTER, FRANK P.—Destruction of Mosses by Lichens. Bot. Gaz. LXXII, pp. 321–5, 1 pl. (1921).

MAMELI, EVA.—1. Ricerche fisiologiche sui Licheni. I. Idrati di Carbonio. Atti Ist. Bot. Univ. Pavia, XVII, pp. 147–57 (1920).

—— 2. Licheni della Sardegna. Tom. cit. pp. 159–73.

—— 3. Licheni della Cirenaica. Tom. cit. pp. 175–83.

—— 4. Note critiche ad alcune moderne teorie sulla natura del consorzio lichenico. Tom. cit. pp. 209–25, 1 pl.

—— 5. Ricerche sulla costituzione della membrana delle alghe Cianofricee. Tom. cit. pp. 257–64.

MELLOR, ETHEL.—Les Lichens vitricoles et leur action sur les vitraux d'église. Comptes Rendus, CLXXIII, pp. 1106–8 (1921).

—— Les Lichens vitricoles et la détérioration des vitraux d'église. Rev. Gén. Bot. XXXIV, pp. 280–6, 4 pls., 4 figs. and pp. 336–45, 4 pls., 4 figs. (1922).

MOREAU, FERNAND.—Recherches sur les lichens de la famille des Stictacées. Ann. Sci. Nat. Bot. Sér. x, 3, pp. 297–376, 4 pls. (1921).
NIENBURG, WILHELM.—Studien zur Biologie der Flechten, I, II, III. Zeitschrift für Botanik, XI, pp. 1–38, 10 figs. (1919).
PAULSON, R.—Ten years progress in Lichenology. Essex Naturalist, XIX, pp. 273–87, 4 pls. (1921).
—— Sporulation of Gonidia in the Thallus of *Evernia prunastri*. Trans. Brit. Mycol. Soc. VII, pp. 41–7, 1 pl. (1921).
PLITT, CH. C.—Preliminary Report...on the Lichens...near Cinchona Botanical Station, Jamaica. Bryologist, XXIV, pp. 60–64 and 70–74 (1921).
RIETZ, G. EINAR DU.—Zur methodischen Grundlage der modernen Pflanzensoziologie, Upsala, 1921; Wien, Adolf Holzhausen, 1921, 272 pp., 38 tables, 22 figs. (1921).
SALOMON, HANS.—Ueber das Vorkommen und die Aufnahme einiger wichtiger Nährsalze bei den Flechten. Jahrbüch. Wiss. Bot. LIV, pp. 309–47 (1914).
SÁNTHA, L.—Untersuchung der Flechten im polarisierten Licht. Botanikai Közlemènyek, XV, pp. 99–101 (1916). (See also Hedwigia, LIX, 1917–18, Beibl. p. 10.)
SAVICZ, V. P.—Zum Studium der Flechten und der Flechtenformation im östl. Sumpfgebiet des Gouv. Pskov. Bull. Jard. Imp. Bot., St Petersburg, XIII, pp. 147–8 (1913).
SERNANDER, R.—Studier öfver lafvarnes biologi. I. Nitrofila lafvar. Svensk Bot. Tidskr. VI, pp. 803–83, 10 figs., 2 pls. (1912). (See also BIORET, Rev. Gén. Bot. XXXIII, pp. 108–200, 1921.)
SHIRLEY, JOHN.—The Thallus of the genus Parmelia. Proc. Roy. Soc. Tasmania, pp. 53–68 (1919).
SMITH, A. LORRAIN.—Handbook of British Lichens. British Museum, Cromwell Road, London, 159 pp., 90 figs. (1921).
STRATO, CL.—Ueber Wachstum und Regeneration des Thallus von *Peltigera canina*. Hedwigia, LXIII, pp. 11–42, 13 figs. (1921).
TOBLER, F.—Die Wolbecker Flechten-Standorte. Hedwigia, LXIII, pp. 7–10 (1921).
VAINIO, ED. A.—Mycosymbiose, Symbiose de deux Champignons. Ann. Soc. Zool.-Bot. Fenn. Vanamo, I, n. 4, pp. 56–60, 1 fig. (1921).
WAREN, H.—Reinkulturen von Flechtengonidien. Akad. Abh. Ofv. Finsk. Vet.-Soc. Forh. LXI, n. 14, 80 pp., 9 pls. (1920). (See BIORET, pp. 25–8, 1921.)
WATSON, W.—Determination of Lichens in the Field. Journ. Bot. LX, Suppl., June, July, 28 pp. (1922).
ZANFROGNINI, CARLO.—Pugillo di Licheni corticicoli della Somalia. La Nuova Notarisia, XXVIII, pp. 145–75 (1917).
ZAHLBRUCKNER, A.—Neue Flechten, IX. Ann. Mycol. XIX, pp. 224–42 (1921).

PARASITES OF SCALE-INSECT FUNGI.

With 3 Text-figures.

By T. Petch, B.A., B.Sc.

In the paper on "Fungi parasitic on scale insects" (Trans. Brit. Myc. Soc. VII (1921), pp. 18–40) it was noted (p. 33) that a black pycnidial fungus with small, brown, narrow-oval spores was found on scale insects in Ceylon, and reference was made to Parkin's suggestion, with which the writer was inclined to agree, that it might be a pycnidial stage of *Myriangium*. A subsequent

study of the genus *Myriangium* has made that suggestion appear improbable, but in the meantime it has been found that H. and P. Sydow had provided a place in systematic mycology for the fungus by instituting the genus *Sirosphaera* (Philippine Journal of Science, VIII C, p. 502, 1913, text-fig. 6).

SIROSPHAERA.

The genus *Sirosphaera* (*Sphaeropsideae*) has globose-conoid, black, subcarbonaceous perithecia, minutely ostiolate, parenchymatous, crowded on a superficial stroma which is composed of rather loose, dark brown hyphae. The basidia are simple, filiform, and hyaline, and bear very minute, continuous, pale brown spores in chains.

The type species, *Sirosphaera botryosa* Syd., was found on living leaves of *Streblus asper* in the Philippines. It forms, *fide* Sydow, a small superficial stroma, composed of dark brown, rather loosely interwoven hyphae, on which the pycnidia are situated, either superficially or with their bases slightly immersed in the stroma, the wall of the pycnidium being easily distinguished from the tissue of the stroma. The wall is parenchymatous and consists of two strata, an outer, several layers thick, brown in colour, with cells 8–10 μ diameter, and an inner one, which is hyaline and composed of minute cells. The whole of the pycnidial cavity is lined with basidia 8–11 μ long, 0·8–1 μ diameter, and the spores are pale brown, 2–2·5 $\times$ 1·5 μ.

Sirosphaera botryosa has been collected in Ceylon on *Memecylon*. In the latter case, however, it was not parasitic on the *Memecylon*, but on the fungus, *Pseudomicrocera Henningsii*, which in turn was parasitic on a scale insect, *Aonidia* sp. The pycnidia in this collection were oval or globose, up to 0·2 mm. diameter, black, rugose, sometimes slightly tomentose. The stroma in section was greenish-black. The spores were brown, oval, 2·5–3·5 $\times$ 2–2·5 μ. The basidia observed were not more than 3 μ high, and here and there the chains of spores arose from the pycnidium wall. In spite of the latter differences, this gathering would appear to be identical with Sydow's species.

Another gathering of this species has been noted in herbarium collections, viz. the Javan specimen issued by von Höhnel as *Myriangium Duriaei* Mont., on *Erythrina*, Buitenzorg, 1907–8. This in Herb. Kew contains effete *Myriangium* stromata bearing the pycnidia of the parasite. The latter are 0·1–0·2 mm. diameter, with brown spores, either oval, 3 $\times$ 2 μ, or globose, 2 μ diameter.

In these last two collections, the hyphae of the *Sirosphaera* penetrate into the host fungus, and the apparent stroma is the original stroma of the host permeated by the hyphae of the parasite.

Another species of *Sirosphaera* has been collected on two occasions in Ceylon, in both instances parasitic on a purple-red or purple-brown stroma which is common in Ceylon on the insects, *Aleyrodes* spp., but which it has not yet been possible to assign to any group. One of these collections, from Hakgala, 5600 ft., is on *Pavetta indica*, and the other, from Peradeniya, 1600 ft., on *Streblus asper*.

In this species, the pycnidia are up to 0·35 mm. diameter, globose, ovoid, or conoid, sometimes turbinate, rugose, at first pruinose, sometimes densely, with minute green particles, and bearing scattered erect hairs, finally becoming black and glabrous, clustered on a black stroma which ultimately covers the purple-brown stroma of the host. Each pycnidium is elevated on a base of stromatic tissue which is greenish-yellow internally. The wall of the pycnidium is thick, parenchymatous, blackish-brown in section with a hyaline inner layer. The ostiola are circular, about 50 μ diameter, not elevated, fringed with yellow or greenish yellow hairs. The green granules consist of irregular hyphae, 4–6 μ diameter, pale greenish yellow by transmitted light, rough, closely septate, sometimes moniliform, sometimes ending in inflated tips or in spore-like spherical bodies up to 8 μ diameter; these hyphae arise from the wall of the pycnidium. The scattered hairs are rigid, up to 44 μ high, 6 μ diameter below, tapering upwards, thick-walled, sometimes nodular, obtuse at the apex. The basidia are simple, 3–9 μ high, but sometimes the chain of spores arises from a short sterigma on a projecting cell of the pycnidial wall. The spores are oval, 2·5–3 × 1·5 μ, or globose, 1·5 μ diameter, pale-brown, sometimes with a clear band across the middle.

This species may be known as *Sirosphaera chlorostoma*. The purple-brown stroma of the host fungus is permeated by the hyphae of the *Sirosphaera* and is blackened internally. In cases where the pycnidia are situated on part only of the host fungus, the remainder retaining its purple-brown colour, the apparently normal part of the host stroma is usually permeated by the parasite, except for a thin cortical zone.

The specimens of *Sirosphaera* which have come under my notice have in all cases been parasitic on entomogenous fungi, i.e. on fungi parasitic on scale insects (including *Aleyrodidae*). It would seem probable, from the description of the type as "quite superficial," that it also was parasitic on an entomogenous fungus.

SIROSPERMA.

Another similar fungus has been described by the same authors (Engler's Bot. Jahrb. LIV (1916), p. 258, fig. 2) as the type of another new genus, *Sirosperma*. It was collected in

New Guinea, parasitic on a *Hypocrella* on *Imperata*. *Hypocrella* is a genus of entomogenous fungi. Professor H. Sydow has kindly furnished me with a specimen from the type collection, which agrees completely with the published description.

The genus *Sirosperma* has black, subcarbonaceous, globose pycnidia, indistinctly ostiolate, superficial, on a subiculum consisting of fuscous hyphae. The spores are minute, ellipsoid, continuous, hyaline, produced in chains from the pycnidial wall, without any basidia. It is said to be near *Sirococcus*, but to differ from the latter genus in the presence of a subiculum and the absence of basidia.

The type species, *Sirosperma Hypocrellae*, has very minute pycnidia, 70–100 μ diameter, crowded together on the surface of the host stroma. Its hyphae overrun the latter and penetrate into it. On the surface of the *Hypocrella* the hyphae are closely septate, with unequally broad segments, like the hyphae of a *Dematium*; within the stroma they are more regular and the segments are longer. The pycnidia have a parenchymatous wall, and are fleshy, not carbonaceous. The spores measure $2–3 \times 1{\cdot}5\,\mu$.

Sirosperma differs from *Sirosphaera* in lacking basidia and having hyaline spores. In both genera the persistence of the spores in chains in the pycnidium is remarkable. Even in freehand sections they retain their position. On staining with methyl violet it is found that the chains are embedded in a hyaline amorphous substance. This substance is not visible in unstained sections, but it stains blue with methyl violet.

In February 1921, I collected a pycnidial fungus at Hunstanton (England), on *Lepidosaphes ulmi* on Hawthorn, the insect having been previously attacked by *Cephalosporium* sp. The material is not in very good condition, but the fungus appears to be referable to *Sirosperma*. The pycnidia are black, globose, obscurely ostiolate, up to 80 μ diameter, scattered over the scale but chiefly along the edge. The wall is rather thick, but the outer layers are more or less disorganised and overlie a thin, brown, parenchymatous layer consisting of polygonal cells, 3–6 μ broad. The spores are hyaline, oval, $1{\cdot}5–2 \times 1\,\mu$, produced in chains. The mycelium of the fungus consists of brown irregular hyphae, 3 μ diameter, closely septate, with abrupt angular bends, sometimes united here and there into thin sheets by lateral fusion. I name this species *Sirosperma sparsum*. In the present instance, it is parasitic on *Cephalosporium* sp. on *Lepidosaphes ulmi*.

BYSSOSTILBE.

In the Fungi of Ceylon, No. 1003 (Journ. Linn. Soc. XIV, 1875, p. 113), Berkeley and Broome described a species as

Hypomyces stilbiger. Its spores were said to be multiseptate and its conidial stage to be stilbiform. As regards the latter character it would not be unique among *Hypomyces* in Ceylon, since *Hypomyces flavolanatus* Petch has a *Stilbum* conidial stage. Its ascospores, however, are decidedly different from those of a *Hypomyces*; on referring to Berkeley and Broome's illustration (*loc. cit.* Pl. V, fig. 26) it will be seen that they figure a long septate spore which divides up into disc-like part-spores, like a rouleau of coins. Actually, the ascospores are filiform, as long as the ascus, and divide into part-spores only as long as broad, the part-spores finally rounding off and becoming spherical spores which retain their original position in lines in the ascus for a considerable time.

Saccardo transferred *Hypomyces stilbiger* to *Berkelella* from the description. As examination of the type showed that it could not be included in that genus, a new genus, *Byssostilbe*, was instituted for it in Ann. Perad. v, p. 296. *Byssostilbe*, in its perithecial stage, is a *Torrubiella* in which the part-spores are as broad as they are long.

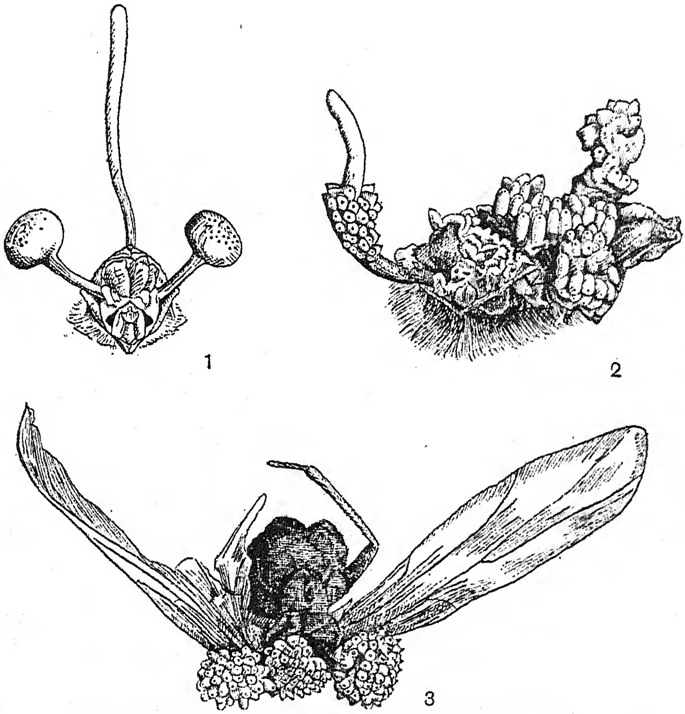
The type species, *Byssostilbe stilbigera*, is parasitic on various species of *Trichia* and *Hemitrichia* in Ceylon. Its conidial stage is the fungus recorded from Ceylon as *Stilbum tomentosum*. Two other species of *Byssostilbe* have since been found in Ceylon, both parasitic on entomogenous fungi, one on *Torrubiella luteorostrata* Zimm., and the other on *Cordyceps dipterigena* B. and Br. Their conidial stages have not yet been observed.

Byssostilbe fusca Petch, n.sp. Perithecia conoid, apex obtuse or papillate, 0·4 mm. high, 0·25 mm. diameter, blackish-brown, darker above, subtranslucent, glabrous. Asci very long, cylindric, capitate, 6–8 μ diam., eight-spored. Spores filiform, as long as the ascus, dividing into spherical part-spores, 1·25–1·5 μ diameter. On the stroma of *Torrubiella luteorostrata* Zimm. on an Aleyrodid on *Murraya exotica*, Hakgala, Ceylon, April 1917. This species differs from *Byssostilbe stilbigera* in the colour and shape of the perithecia; in the latter species, the perithecia are pale yellow to amber, elongated flask-shaped, up to 0·6 mm. high, 0·2 mm. diam.

Byssostilbe tomentosa Petch, n.sp. Mycelium usually covering the stroma of the host fungus (*Cordyceps*) with a thin compact white film. Perithecia clustered, forming continuous groups on the perithecial or conidial stromata of the host fungus, conoid, 0·45 mm. high, 0·3 mm. diameter, with a dense tomentose coat, 0·05 mm. thick, except at the apex, adherent laterally but readily separable, white; ostiolum conical, yellow, subtranslucent. Asci 4 μ diameter, very long, capitate. Spores filiform, as long as the ascus, 1 μ diameter, dividing into part-spores

1·5–2 μ long. On *Cordyceps dipterigena* on a fly (*Mydaea* sp.), on *Psychotria*, Hakgala, March 1922. The fully rounded part-spores have not been seen in this species, but there does not appear to be any doubt that it belongs to *Byssostilbe*, not *Torrubiella*.

The second species is of interest in showing how nature sometimes lays traps for the systematic mycologist. *Cordyceps dipterigena* is remarkably regular in structure and habit. The



Byssostilbe tomentosa on *Cordyceps dipterigena*.

insect attacked bears, as a rule, three clavae, a pair of ascigerous clavae from the thorax, and a single conidial (or barren) clava from the abdomen. I take the latter to be a conidial clava, but I have not yet detected the conidia on it. When attacked by *Byssostilbe tomentosa*, perithecia are produced on the body of the insect, and in irregular groups over the ascigerous stromata, while on the conidial stroma, a cluster of perithecia encircles the clava, so that it resembles a *Cordyceps* with superficial perithecia. If such a specimen were collected alone, it would almost

certainly be described as a new *Cordyceps*. Fortunately, in the present instance, it was gathered with numerous other specimens of *Cordyceps dipterigena*.

The accompanying figures show normal and parasitised specimens of *Cordyceps dipterigena* respectively. Fig. 1 is the normal fungus with the usual pair of perithecial stromata and the single conidial stroma, viewed from the head of the insect, and magnified four diameters. Fig. 2 is a parasitised specimen, viewed laterally, magnified six diameters; the perithecial stromata of the *Cordyceps* are hidden by the perithecia of the *Byssostilbe*, while the conidial stroma is encircled by a cluster of these perithecia. Fig. 3 is another parasitised specimen, in which external mycelium is almost completely lacking; the heads of the perithecial stromata are densely covered with the perithecia of the *Byssostilbe*, and a third cluster occurs on the insect between them. The stalks of the perithecial stromata in this latter example are short and are not seen in the figure; they do not bear perithecia of the *Byssostilbe*.

THE GENUS CLADOSTERIGMA PAT.

By T. Petch, B.A., B.Sc.

The type species of the genus *Microcera*, *Microcera coccophila* Desm., is parasitic on scale insects. Consequently it is of interest to ascertain whether the other species which have been assigned to that genus have the same habit, or whether they are really cogeneric with the type species. Several of these species have already been reviewed in the "Nectriae parasitic on scale insects" (Trans. Brit. Myc. Soc. VII, pp. 99, 100), but a few were not accessible when that paper was written. One of these in particular, *Microcera Clavariella* Speg., was considered a probable entomogenous fungus, as it was described as occurring on living leaves of *Eugenia*; and in response to my enquiry, Dr C. Spegazzini kindly forwarded me the type and other collections of that species from South America.

Examination of the type specimen showed that its structure differed from that of *Microcera coccophila*, and that it could not be included in *Microcera*. It has basidia covering the entire surface of the synnema, like a *Clavaria*. And on further consideration it was evident that the fungus was identical with *Cladosterigma fusisporum* Pat., originally described as occurring on living leaves of a *Myrtaceae*, from Ecuador.

Spegazzini described *Microcera Clavariella* in Fungi Guaranitici, Pugillus I (ante 1886), as occurring on living leaves of *Eugenia*, but not causing any spot. The sporodochia were simple, cylindrical, minute, 250–500 μ high, 50–80 μ diameter, obtuse at the apex, erect, waxy, viscid, rigid, yellowish or flesh-coloured, glabrous, solitary or in groups up to ten, arising from a lenticular, parenchymatous stroma, 0·5–1 mm. diameter, of the same colour as the sporodochia, embedded in the tissues of the leaf. The basidia covered the whole surface of the sporodochia, and were clavate, obtuse or acute at the apex, appearing covered with short longitudinal ridges, hyaline, monosporous, 10–15 × 3 μ. The conidia were clavate, slightly curved, 3–5 septate, not constricted, hyaline, ends acute, 20–27 × 1·5–2 μ.

I have examined three gatherings of this species *ex* Herb. Spegazzini, viz. the type, No. 3483, Caaguazu, Brazil, January 1882; No. 3787 (F. H. 164), on leaves of *Eugenia*, Paraguay, in the forests, April 1883; and No. 4057, f.g.n. 428, Guarapi, October 1883. The two latter differ from the type in minor details, due to more advanced development.

The genus *Cladosterigma* was instituted by Patouillard in "Champignons de l'Equateur," Bull. Soc. Myc. France, 1892, p. 138, t. XII, fig. 3, the generic description being—Fungi biophili, foliicoli, gelatinosi, clavariaeformes, hymenio basidifero undique vestiti; basidia clavata, sterigmatica; sterigmata brevia apice dendroideoramosa; sporulae hyalinae, simplices.

The type species, *Cladosterigma fusisporum*, had cylindrical caespitose clavae, simple, forked, or variously branched, white, gelatinous, pellucid, 0·5–1 mm. high, arising from a black sclerotium, 0·5–1 mm. diameter, immersed in the leaf in a brown circular spot, the spots being scattered or confluent, 2–8 mm. broad. The basidia were claviform, attenuated below, obtusely rounded above, 10–13 × 6 μ, and the sterigmata 4–6 μ high, "denticulato-ramosa." The conidia were fusiform, elongated, acute at either end, guttulate, 16–20 × 5–6 μ. Some of Patouillard's figures were reproduced in Engler-Prantl's Pflanzenfamilien.

Both species occur on living leaves of *Myrtaceae*, and the synnemata or clavae arise from a compact stroma within the tissue of the leaf, breaking through the epidermis in clusters. The description of *Microcera Clavariella* states that there is no spot on the leaf, while Patouillard described and figured a circular brown spot overlying and surrounding each stroma. This difference appears to be due merely to the age of the fungus. In the type specimen of *Microcera Clavariella* the spots are not evident on one side of the leaf, and minute and pale-brown on the other, but other specimens in Herb. Spegazzini

bear circular brown spots exactly resembling those figured by Patouillard. Similarly, the description of the immersed stroma as concolorous with the synnemata in the one case, and black in the other is also to be attributed to a difference in the stage of development of the specimen examined.

The synnemata may be short and forked towards the apex, or forked at various heights in stag's horn fashion. This is the condition figured by Patouillard. But in many cases branching occurs at the base only, so that the free clavae are long, up to 1 mm. high, and slender, not inflated above; and the cluster has then quite a different appearance, especially as the clavae then become variously curved in drying and resemble, at first sight, extruded tendrils, rather than stilboid synnemata.

The dry clavae are subtranslucent, horny-looking, and brittle. They do not swell up in water, and are probably more correctly described as waxy than as gelatinous. The basidia in the specimens examined were clavate or cylindrico-clavate, and it would appear that either the branched sterigma is evanescent, or that some of the basidia may bear only simple, rather blunt sterigmata.

The chief difference between the two descriptions lies in the characters given for the conidia. *Microcera Clavariella* was said to have septate spores, and the specimens examined showed fusiform or clavate spores, straight or slightly curved, acute at at the tips, 1–3 septate, $15–21 \times 2–2{\cdot}5\,\mu$, appearing rough when stained with iodine. The spores were not abundant. *Cladosterigma fusisporum* was said to have fusiform, continuous spores, but as they were described and figured as multiguttulate, it is probable that they were immature. A more serious difference is the measurement given by Patouillard, viz. $16–20 \times 5–6\,\mu$, which indicates a much broader spore than that found in *Microcera Clavariella* by Spegazzini and the writer. Patouillard's figures show a ratio of length to breadth, 11·5 to 2, and 9 to 2·5, but even that is greater than in the available specimens of *Microcera Clavariella*.

However, the identity of habitat and structure of the two species would appear to make it improbable that they are distinct, in spite of the discrepancy of the spore measurements. *Microcera Clavariella* is certainly *Cladosterigma*, and it does not appear to be different from *Cladosterigma fusisporum*. The species must therefore be known as *Cladosterigma Clavariella*, and the genus *Cladosterigma* must be included in *Stilbaceae-Phragmosporae*, not in *Stilbaceae-Amerosporae*.

Three species of the same general structure as *Cladosterigma* have been found in Ceylon, all of them parasitic on insects. They differ, however, from *Cladosterigma* in having simple,

rigid, filiform sterigmata and continuous spores. For these I propose a new genus, *Trichosterigma.*

Trichosterigma gen. nov. *Stilbaceae.* Clavariaeform, covered with spherical, subglobose, or ovate basidia, each bearing an apical, rigid, filiform sterigma; conidia terminal, solitary, hyaline, continuous.

Trichosterigma clavisporum Petch, n.sp. Mycelium covering the insect in a matted glabrous sheet and spreading out in a fimbriate margin over the substratum. Clavae arising from the mycelium, erect, terete, simple, up to 8 mm. high, 0·35 mm. diameter below, tapering upwards, brownish white (dry), smooth. Basidia crowded, ovate, up to 8 μ high, 2–3 μ diameter, rounded or attenuated at the apex. Sterigmata rigid, simple, filiform, 5–9 μ high. Conidia hyaline, continuous, clavate, $4–8 \times 1–1·5\ \mu$. On a caterpillar attached to a living leaf, Peradeniya, January 1912.

Trichosterigma arachnophilum Petch, n.sp. Mycelium covering the body of the insect and forming a flattened pulvinate, pale yellow, somewhat spongy, tomentose stroma, with a fimbriate margin. Clavae arising from the stroma, pallid yellow, cylindric, up to 4 mm. high, 0·15 mm. diameter below, tapering slightly upwards, smooth, simple. Basidia scattered or crowded, globose, 3 μ diameter, or subglobose, up to $6 \times 5\ \mu$. Sterigmata simple, rigid, about 2 μ long. Conidia narrow-oval, ends acute, continuous, $4–8 \times 2\ \mu$. On a spider attached to a living leaf, Hakgala, March 1922; Peradeniya, March 1909; Peradeniya, March 1917. This species is the conidial stage of *Torrubiella flava* Petch. The specimen from Peradeniya, March 1909, differs in colour, being lilac grey. A similar colour difference occurs in *Gibellula elegans* P. Henn., which is also parasitic on spiders.

Trichosterigma attenuatum Petch, n.sp. Mycelium scanty, brownish, overrunning the host insect. Clavae arising from the body or legs of the insect, usually from the joints, or along the margins of the wing covers. Clavae pale brown (dry), up to 6 mm. long, 0·2 mm. diameter below, tapering upwards to 0·08 mm. diameter, rigid, slightly inflated at the apex, terete, smooth, bristling with hyaline sterigmata when magnified. Basidia oval or flask-shaped, $8–10 \times 3\ \mu$, attenuated into a rigid simple sterigma, up to 26 μ long, 1·5 μ diameter at the base, tapering upwards. Conidia solitary, hyaline, continuous, oval or lozenge-shaped, usually acute at each end, $6–7 \times 3–5\ \mu$. On a Pentatomid on bark, Hakgala, May 1912. The insect in the type specimen bears more than forty clavae, but many of them have been broken.

SOME ADDITIONAL RECORDS OF SURREY RESUPINATE HYMENOMYCETES.

With 8 Text-figures.

By E. M. Wakefield and A. A. Pearson.

The present list contains a larger proportion of Heterobasidiae than were contained in our previous lists, and this group will evidently well repay further attention. The specimens however must be studied soon after gathering, when the hymenial cells are turgid. They soon collapse on drying, and little or no trace of the plant may remain. Some species are of such a delicate colourless nature that their presence is only made manifest to the naked eye by the faintly pruinose appearance of the wood on which they grow. A lens reveals the thin transparent film, and if gathered at a favourable stage of development the microscopic characters are easily detected. Soon after maturity however the hymenial elements are apt to become indistinct, and often only the spores can be found. This especially applies to species of the genus Tulasnella. These have frequently been found in an imperfect condition, and it is probable that many more exist than have been described. The two new species included in the present list are both exceedingly thin and delicate even when at their best, and are easily overlooked.

Corticium bisporum Bourd. et Galz. in Bull. Soc. Myc. Fr. XXVII, 1911, p. 240. ? *Hypochnus bisporus* Schroet., Pilz. Schles. p. 415.

Effused, indeterminate, white to cream, easily separable, very thin. Hymenium forming a continuous pellicle above the loose cottony subiculum, often wrinkled or rather bullate when fresh but becoming quite smooth as it dries. Basidia arising from branched hyphae in a corymbose manner, clavate, 15–25 × 6–7·5 μ; sterigmata constantly 2, short (4–5 μ), divergent. Spores ovate, elliptical or somewhat oblong, hyaline, smooth, 8–11 × 4·5–6 μ. Basal hyphae very loosely interwoven, septate, very rarely with clamp-connections, 4–6 μ in diameter. Rod-shaped crystals present in abundance in the subhymenial tissue.

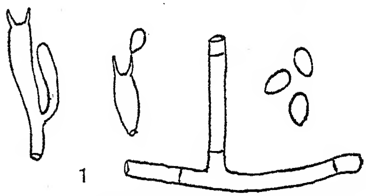


Fig. 1. *Corticium bisporum.* × 550.

On a fallen branch, East Horsley, Jan. 1922, A.A.P.

We are indebted to M. l'Abbé Bourdot for the identification

of this species. The macroscopic appearance is similar to that of *Corticium arachnoideum*, but the characters of spores and basidia differ.

The species as understood thus by Bourdot differs in several details from the original description of *Hypochnus bisporus* by Schroeter, notably in the size of the spores. Schroeter described his species as having spores 5×3–$3{\cdot}5\,\mu$, considerably smaller than those of the present species. Further the hyphae of *H. bisporus* were said to have clamp-connections, from which one would infer that they were fairly frequent. In the present form, however, these structures are so rare as to be easily overlooked unless careful search is made.

On the other hand, Schroeter's type specimen apparently no longer exists (cf. von Hoehnel and Litschauer in Ann. Myc. IV, 1906, p. 288), and in the absence of any information as to what it may have been, the name may well be kept for this species, which is characterised by its constantly 2-spored basidia. It should however be cited as above.

Corticium diademiferum Bourd. et Galz. in Bull. Soc. Myc. Fr. XXVII, 1911, p. 244.

Effused, adnate, very thin, whitish to cream, margin indeterminate. Basidia 15–21×5–$6\,\mu$ with 6–8 sterigmata. Spores subglobose, 4–5×3–$4\,\mu$. Hyphae thin-walled, with clamp-connections, 3–$5\,\mu$.

On bark of a birch log, Effingham, Mar. 1921, A.A.P.

The above description is taken from that given by Bourdot and Galzin. The specimen cited was so determined by M. Bourdot, but has spores which are ovate rather than subglobose. The basidia are of the characteristic shape of the group *Urnigera* B. and G.

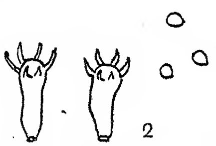


Fig. 2. *Corticium diademiferum.* × 550.

Fig. 3. *Corticium tulasnelloideum.* × 550.

Corticium tulasnelloideum von Hoehn. et Litsch. in Sitz. K. Akad. Wiss. Wien, Math.-naturwiss. Kl., Bd. CXVII, I, 1908, p. 1118.

Effused, very thin, closely adnate, appearing as little more than a pruinosity on the surface of the matrix. Hymenium smooth and continuous when best developed. Basidia clavate, 12–20×6–$8\,\mu$ with 2–4 sterigmata, 6–$7\,\mu$ long. Spores broadly elliptical to subglobose, very finely and closely echinulate,

4·5 × 3 μ or 4 μ in diameter. Hyphae distinguished with difficulty, recorded as 2·5 μ in diameter, with clamp-connections, by Bourdot and Galzin.

On rotten decorticated wood, Mulgrave Woods, Yorkshire, C. Crossland, Oct. 1912; Horsley, Mar. 1921, A.A.P.

This species may be more common than the above two widely separated records would indicate. It is one of the very delicate, easily overlooked forms. The first specimens sent by the late Mr C. Crossland were in excellent condition, as his consignments always were, but the species was not then recorded because it was hoped that further confirmatory specimens would be received. Until the Horsley specimen, however, none has been forthcoming. The Horsley gathering is much more scanty, but the habit and characteristic spores leave no doubt that it is the same species.

The measurements of spores and basidia given above are from the Mulgrave specimen, and agree with those of the type, a fragment of which was kindly communicated by M. Bourdot.

SACCOBLASTIA Moeller, Protobasidiomyceten, 1895, p. 162.

Effused, floccose or gelatinous. Basidia cylindrical, transversely septate, arising from a probasidium which remains as a lateral, sac-like attachment at the base of the basidium. Sterigmata lateral. Spores hyaline, smooth.

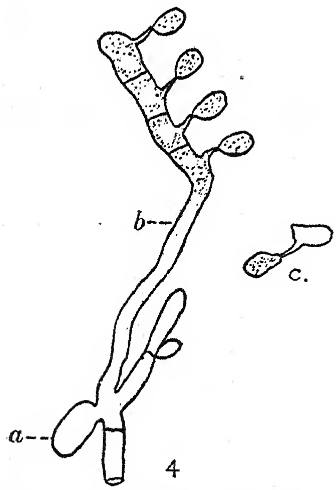


Fig. 4. *Saccoblastia sebacea.* *a.* Probasidium. *b.* Basidium. *c.* Germinating spore. × 550.

Saccoblastia sebacea Bourd. et Galz. in Bull. Soc. Myc. Fr. XXV, 1909, p. 15.

Effused, greyish, thin, fleshy, at first rather firm in texture, later becoming slimy-gelatinous. Hymenium delicately pruinose and somewhat granulose when in good condition, as seen under the lens. Probasidium 15–25 × 7–9 μ, ovoid to oblong, pendulous, collapsing as the basidium matures and often breaking away in the preparation of sections. Basidia cylindrical, curved, 5–8 μ wide above, narrowing gradually to a more or less elongated pedicel below, with 2–3 transverse septa in the upper part. Sterigmata lateral, conical, 8–10 × 2 μ. Spores broadly elliptical, laterally apiculate, smooth,

hyaline, 7–10 × 4·5–7 μ, germinating immediately to produce secondary spores of similar form. Hyphae frequently septate, without clamp-connections, often constricted at the septa, 3–5 μ in diameter; contents, as also those of the probasidium and young basidia, granular and with numerous oil-drops.

On old stumps of beech, birch and oak, Horsley, Feb., Mar. and April, 1922.

In the original description the species is given as "mucoso-gelatinosa" in texture. The excellent series of specimens collected at Horsley showed that this was so only in the later stages. When at its best the fungus has somewhat the consistency of *Corticium confluens*, and is beautifully pruinose with the projecting basidia and spores.

Platygloea Peniophorae Bourd. et Galz in Bull. Soc. Myc. Fr. XXV, 1909, p. 17.

Fungus starting as small patches, then becoming effused over the surface of the host, very thin, whitish to pale buff, margin pure white, somewhat byssoid. Hymenium pruinose under a lens, but interrupted here and there by masses of spores (conidia?) which are aggregated in semi-liquid globules. Basidia curved, transversely 2–3 septate, 5 μ wide. Sterigmata filiform, flexuose, up to 40 μ long. Spores elliptical with one side depressed, and with a pronounced lateral, oblique apiculus, 8–9 × 5–5·5 μ, germinating to form secondary spores of similar size and shape.

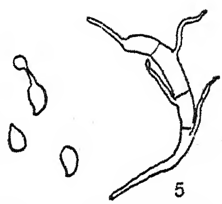


Fig. 5. *Platygloea Peniophorae.* × 550.

Growing over the hymenium of *Corticium praetermissum*, and probably also *Peniophora pubera*, Horsley, Mar. 1922, A.A.P.

The fungus as described above from the specimens cited differs in some particulars from the original description. In particular our fungus has not dried "horny and greyish," but as a thin, white, markedly pulverulent film. Nor were any sterigmata found as long as those described by Bourdot and Galzin (90 μ and more). The longest sterigmata found in our specimens were 40 μ long, and these were exceptional. It is probable that both these points of difference are due to the fact that our fungus was younger and therefore less thick than the specimens seen by the authors of the species. It is well known that the length of basidia and of the sterigmata of the Auricularineae varies according to the depth of origin in the tissue.

Tulasnella violacea (Johan Olsen) Juel in Bihang K. Sv. Vet.-Akad. Handl. XXIII, Afd. III, No. 12, 1897, p. 22.

Effused, very thin, deep violet when fresh but drying to pale

lilac. Basidia subglobose to oblong, 12×8–$11\,\mu$; sterigmata 8–10×6–$7\,\mu$. Spores subfusiform, curved, $12 \times 7\,\mu$. Basal hyphae septate, without clamp-connections, 4–$6\,\mu$ in diameter.

In a large patch on the bark of an old birch log, Weybridge, Jan. 1922.

The spores of this specimen agree better in size with those of the var. *lilacea* Bres. than with those of the type, which were described as $15 \times 8\,\mu$. It seems probable that the species varies both in colour and in spore-size. The shape of the spores is characteristic.

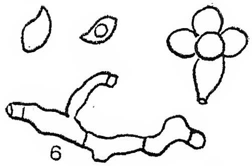


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Fig. 6. *Tulasnella violacea.* × 550.

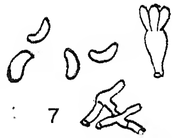

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Fig. 7. *Tulasnella allantospora.* × 550.

TULASNELLA ALLANTOSPORA Wakef. et Pears. sp. nov.

Fungus effusus, tenuissimus, ceraceus, hyalinus vel levissime lilacinotinctus. Basidia obovata, 7–$10 \times 6\,\mu$. Sterigmata elliptica, 7–$9 \times 5\,\mu$. Sporae cylindraceae, curvulae, utrinque attenuatae, 9–10×3–$4\,\mu$. Hyphae basales 2–$3\,\mu$ septatae, non nodosae.

On decorticated coniferous wood, East Horsley, April 1922, A.A.P.

This species forms an exceedingly thin film, scarcely visible to the eye when looked at direct except as a slight dullness of the surface of the wood. When the specimen is tilted so as to catch the light, however, the fungus appears as a delicate "bloom" with a very faint pinkish or lilac tinge. The species is recognisable by its delicacy and the small curved spores.

TULASNELLA MICROSPORA Wakef. et Pears. sp. nov.

Fungus effusus, tenuissimus, pulverulentus, pallide lilacinus. Basidia obovata vel ellipsoidea, 7–10×5–$6\,\mu$. Sterigmata elliptica, $2{\cdot}5$–$3{\cdot}5 \times 2$–$3\,\mu$. Sporae ovatae, $5{\cdot}5$–6×3–$3{\cdot}5\,\mu$. Hyphae basales ramosae, septatae, non nodosae, 2–$3\,\mu$ diametro.

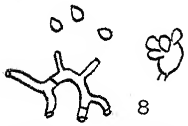

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Fig. 8. *Tulasnella microspora.* × 550.

On rotten coniferous wood, East Horsley, Mar. and April 1922, A.A.P.

The species is probably not uncommon, but it has rarely been found in a condition good enough for description. The colour when dry is very like that of *T. violacea*, but the small size of spores and hyphae is distinctive for *T. microspora*.

The following species are also additional to our previous lists for Surrey:

Corticium caeruleum Fr., *Peniophora subalutacea* (Karst.) v. H. and L., *Odontia stipata* (Fr.) Quél.

THE PRODUCTION OF FRUIT-BODIES OF COPRINUS COMATUS IN LABORATORY CULTURES.

By Irene Mounce, M.A. (British Columbia), Hudson's Bay Company Research Fellow, University of Manitoba.

I. Introduction.

Brefeld, in his Untersuchungen, states that the large fruit-bodies of *Coprinus comatus* and *C. atramentarius* are very easily raised in dung cultures; but, unfortunately, he gives us no details of the method he employed*. Hitherto, no one seems to have confirmed Brefeld's results with these two species. Professor Buller has informed me that he has twice attempted to obtain fruit-bodies of *Coprinus comatus* on sterilised horse-dung balls contained in large crystallising dishes but that, although the mycelium grew well and continued living for many months, in neither of his cultures did fruit-bodies ever appear. Since the fruit-bodies of *Coprinus comatus* are of large size and edible, it seems well worth while to endeavour to elucidate the conditions under which they may be brought into existence.

Coprinus comatus and *C. sterquilinus* appear to be closely related species, for not only do they resemble one another in general form, in the possession of an annulus, and in having a scaly pileus, but their mechanisms for the production and liberation of spores are practically identical†.

Coprinus sterquilinus fruits readily in sterilised horse-dung cultures. Whilst studying the homothallism of this species, I made a large number of such cultures and found that normal fruit-bodies always appeared upon them within 24–31 days from the time the spores were sown‡. The production of fruit-bodies

* O. Brefeld, Untersuchungen, Heft VIII, Autobasidiomyceten, 1889, p. 39.

† A. H. R. Buller, Die Erzeugung und Befreiung der Sporen bei *Coprinus sterquilinus*, Pfeffer-Festschrift, identical with Jahrb. f. wiss. Bot. LVI, 1915, pp. 299–329, Taf. II and III.

‡ I. Mounce, Homothallism and the Production of Fruit-bodies by Monosporous Mycelia in the Genus Coprinus, Trans. Brit. Myc. Soc. VII, 1921, p. 203; also Homothallism and Heterothallism in the Genus Coprinus, ibid. 1922, p. 259.

was not affected by the origin of the mycelium; for the mycelium, whether it originated from one spore only or from many spores, always grew rapidly and produced a fruit-body within a month. Since *Coprinus sterquilinus* fruits so readily in pure horse-dung cultures, it was thought that *C. comatus*—its near relative—might do so too. However, a series of experiments with dung cultures has convinced me that this supposition is erroneous. The fact is that, although *Coprinus comatus* can be caused to fruit in laboratory cultures, the cultures require to be made in a particular manner and, even then, fruit-bodies appear upon them only after the mycelium has been growing for several months.

II. Experiments and Results.

During the autumn of 1920 I made ten cultures of *Coprinus comatus* on large masses of sterilised horse dung contained in crystallising dishes covered with glass plates. One of the cultures was inoculated with spores from a spore-deposit, another with a small piece of a spore-laden gill taken from a fruit-body that was shedding spores, and the remaining eight with a small piece of tissue procured from the inner side of a stipe. As a result of these inoculations a heavy white mycelium was produced which, in the course of 20–28 days, entirely covered the medium in crystallising dishes nine inches in diameter. The mycelium derived from the spores required a few more days to cover the medium than that derived from a stipe, on account of the fact that the spores took some time to germinate while the piece of tissue removed from a stipe produced rapidly growing hyphae immediately. Several of the mycelia developed heavy white cords on the under surface of the medium and one gave rise to woolly knots on the cords; but, although all the ten mycelia grew vigorously, in the end not one of them developed fruit-bodies even of the most rudimentary kind.

Various changes were made in the conditions of cultivation of the fungus in an attempt to accelerate fruit-body production. Some of the mycelia were placed in the dark, one in bright sunlight, and the rest in diffused daylight; but the results were all negative: no fruit-bodies appeared.

Falck* found that fruit-body production in *Merulius domesticus* is accelerated in artificial cultures by a series of transfers, a mycelium which has just covered the medium in one vessel being transferred to a second vessel containing the same medium, and the mycelium which has just covered the medium in this second vessel being transferred to a third vessel, and so

*R. Falck, Die Fruchtkörperbildung der im Hause vorkommenden holzzerstörenden Pilze in Reinkulturen und ihre Bedingungen, Mycologische Untersuchungen und Berichte, 1, 1913, p. 62.

forth. Such a series of transfers I made with a mycelium of *Coprinus comatus*. A stipe-culture was growing on sterilised horse-dung balls contained in a crystallising dish five inches in diameter. As soon as the mycelium had covered the medium, a small piece of mycelium-covered dung was removed and placed in a second similar dung-dish. Four such successive transfers were made and it was found that it took the mycelium 10–11 days to cover the medium in each dish. Although all the four cultures were maintained for months, no fruit-bodies were produced upon them; yet the mycelia were vigorous and, as shown by their abundant clamp-connections, they were all *secondary*, i.e. in that sexual condition which the mycelia of Hymenomycetes normally attain before the development of sporophores takes place*.

Finally, at the suggestion of Professor Buller, deep culture vessels, instead of shallow ones, were employed, and the culture medium was covered with a thick layer of soil. Two such deep cultures were made in the following manner: (1) A specimen jar 11 inches high and 3 inches in diameter was filled to a depth of 3 inches with a layer of horse dung mixed with sawdust. The mixture was packed down and then the jar was filled to within an inch of the top with sifted black soil. The whole was then covered with a glass plate and sterilised in flowing steam for one hour on each of three successive days. After sterilisation had been accomplished, two vertical holes were made through the six-inch layer of soil with a sterilised glass rod, and through these holes small pieces of mycelium-covered dung taken from a stipe-culture were pushed well down into the layer of dung and sawdust below. (2) A three-litre beaker was filled to within three inches of the top with a mixture of horse dung and sawdust resembling that used for the first culture. After being packed down, the mixture was covered with a two-inch layer of sifted black soil. The beaker and its contents were then sterilised and the culture-medium inoculated in the manner already described.

The inoculation of the culture medium in the two vessels was effected on January 7, 1921. After inoculation, both vessels were set on a table near a window in the laboratory and each was covered with a large bell-jar. The loose glass plate resting on the top of each vessel and the enveloping bell-jars served to reduce the rate of evaporation from the surface of the soil to a minimum. Indeed, evaporation took place so slowly that it was found unnecessary to water the cultures during the ten months which elapsed before they fruited.

* Cf. I. Mounce, Homothallism and the Production of Fruit-bodies by Monosporous Mycelia in the Genus Coprinus, Trans. Brit. Myc. Soc. VII, 1921, pp. 198–200.

Within a week after the inoculation of the two vessels, the inoculation holes became filled with dense white mycelium. In the specimen jar, at the end of twenty days, the mycelium had completely covered the surface of the culture medium with fine white silky hyphae; and thin almost invisible hyphae had made their way through the soil on both sides of the holes. In the three-litre beaker, the mycelium grew in a similar manner and, at the end of six weeks, it had completely covered the medium.

A little later, in each culture, woolly knots of mycelium appeared on the mycelial strands that traversed the upper surface of the soil layer, but for a long time no further changes could be observed.

During the summer no fruit-bodies were produced, but toward the end of September, i.e. almost nine months after inoculation, a tiny fruit-body rudiment was observed in the specimen jar coming up at the surface of the soil. The rudiment developed rapidly and, in the course of a few days, became converted into a very large normal fruit-body of *Coprinus comatus*, which elongated its stipe, expanded its pileus, and shed an abundance of spores within a week from the time the rudiment was first noticed. The spores were found to germinate readily in potato agar and fairly well in dung agar.

In the specimen jar, about three weeks after the fruit-body just described had shed its spores, and about ten months after inoculation, many white mycelial knots appeared on the outer cylindrical surface of the soil and a few centimetres below the soil's upper surface. Ten days later three new fruit-bodies, which had originated in tiny crevices beneath the soil's surface, had pushed their way through the soil into the air. They were creamy white in colour, they had a smooth, gelatinous, oily-looking surface, and they were somewhat conical in shape with a base about 5 mm. in diameter. Five days later they were 7 cm. high and each of them was distinctly divided into pileus and stipe. The pilei, which shaded from the cream colour below to a deep buff at their apices, showed signs of becoming scaly, but each had the annulus still attached to its base. After ten days, in each of the three fruit-bodies, the stipe was rapidly elongating, the annulus had become detached from the base of the pileus and had fallen upon the stipe, expansion of the pileus had begun, the gills were passing through shades of red to black, and it was evident that the spores were maturing. During the next two days, the three pilei opened and discharged vast numbers of spores.

In the meanwhile, the second or beaker culture of *Coprinus comatus* had produced a single fruit-body which shed its spores five days before the three fruit-bodies just described. The de-

velopment of this fruit-body was quite normal except that the pileus became somewhat withered in appearance owing to the fact that maggots invaded the culture shortly after the glass cover had been removed to allow the fruit-body to develop without mechanical hindrance. Two weeks after this first fruit-body had shed its spores the mycelium produced three more fruit-bodies. Unfortunately, however, owing to the ravages of the maggots in the culture medium, these three fruit-bodies never fully matured.

From the facts given above it is evident that a total of four fruit-bodies was obtained in each of the two cultures. Thus it has been demonstrated that, under suitable conditions, *Coprinus comatus* can be caused to fruit in a perfectly normal manner in the laboratory.

The beaker culture contained six times as much food material as the jar culture, and yet the two cultures began to fruit within a month of each other, i.e. they were fruiting almost simultaneously. It is also remarkable that, while the two cultures were fruiting in the laboratory, scores of wild fruit-bodies of *Coprinus comatus* were coming up just outside in the botanical garden. These facts suggest that there may be a periodicity in the development of *C. comatus* comparable with that of *C. sterquilinus*. With *C. sterquilinus*, after the sowing of the spores on sterilised horse dung, fruit-bodies are produced at the end of a month with great regularity, always provided that the cultures are kept moist and free from infection. Perhaps with *C. comatus* this necessary period of development is a longer one, occupying some nine or ten months instead of one. Whether or not it is possible to shorten this developmental period can only be decided by further experiment.

III. Summary.

1. Brefeld's statement that *Coprinus comatus* fruits readily in dung cultures has not been verified; for, when grown upon bare horse-dung balls, the mycelium remained sterile.

2. Eight fruit-bodies of *Coprinus comatus* have been obtained in the laboratory by growing a mycelium in the secondary (clamp-connection producing) condition upon a sterilised mixture of horse dung and sawdust buried beneath a thick layer of soil at the bottom of deep culture vessels.

3. The fruit-bodies raised in the laboratory were of large size, were perfectly normal in general appearance, and produced spores which germinated readily.

4. The interval between the inoculation of the culture medium with mycelium and the production of fruit-bodies was from nine to ten months.

The investigation recorded above was carried out in the Botanical Department of the University of Manitoba during my tenure of the Hudson's Bay Company Research Fellowship. In conclusion, I desire to express my sincere thanks to Professor A. H. Reginald Buller for suggesting the investigation and for valuable advice during its progress.

NOTES ON SOME BRITISH PYRENOMYCETES.

By Sir H. C. Hawley.

The following short notes deal with a few fungi collected in the last ten years or so. They do not profess to deal with them exhaustively. Species which are apparently new to the British Isles are indicated by an asterisk. It is hoped that the attention of other members of the British Mycological Society may be drawn to this interesting group. Meanwhile the writer would be grateful for any specimens sent to him.

Sordaria platyspora Phill. and Plowr. in Grev. VI (1877), p. 28, t. 94, f. 2.

This plant was described as having perithecia with short stiff hairs, sessile cylindrical asci, and spores nearly circular, 20 × 18 μ, 2–3 μ thick. It is also recorded from Scotland (Trans. Brit. Myc. Soc. IV (1913), p. 68). In 1912 I found on rabbit dung in Sussex a fungus with similar hairy perithecia, subsessile asci and disciform spores, 20–21 × 16–17 μ, 6 μ thick. I concluded, notwithstanding the thicker spores, that it was the same. On further consulting the literature, I found that Winter had described a form *major* of *S. discospora* Niessl with spores 17 × 14–15 μ. The spores of typical *S. discospora* are given as 12–14 × 10 μ, or according to Traverso (Flor. Ital. Crypt. I, Pyren. (1907), p. 920), 10–14 × 8–11 μ. Phillips and Plowright also described *Sordaria microspora* with similar but still smaller spores. Spore size is very variable in the Sordariaceae, but it seems better for the present to maintain two distinct species, the one with spores 10–14 × 8–10 μ, the other with spores 17–21 × 15–18 μ—the thickness in both varying from 3–6 μ, rather than to follow Traverso in making *S. platyspora* a synonym of *S. discospora*. At the same time there seems no doubt that *Sphaeria scatigena* B. and Br. in Ann. Mag. Nat. Hist., Ser. III, VII (1861), p. 452 (Notices No. 972), (*Hypocopra* Sacc. Syll. I, 243) is the same as *Sordaria platyspora*—which should be regarded as a synonym of *Sordaria scatigena* (B. and Br.).

Neopeckia fulcita (Bucknall) Sacc. *Lasiosphaeria fulcita* Buck. in Proc. Bristol Nat. Soc. v (1887), p. 126.

This occurred at Lytchett Matravers, Dorset, July, 1922, on rotting bark of *Prunus Laurocerasus.* It differed from the Bristol specimens at Kew in being on bark instead of on bare wood, in being almost completely superficial instead of with base immersed and in having more hairy perithecia which had not collapsed in folds. The Lytchett perithecia were indeed very evidently hairy under a hand-lens. No paraphyses were seen but the asci were involved in a diffluent mass. In other respects it agreed exactly. The fungus in some ways suggests *Melanopsamma pomiformis* Sacc. but is hairy and with spores becoming more truly brown. It is probably uncommon.

Lasiosphaeria sulphurella Sacc. in Mich. I (1878), p. 440.

This species was collected in Lincolnshire in 1908. The cell-walls of the perithecia are of a yellowish context, not in any way carbonised. It does not appear common but was recorded from Kew (Grev. XVI (1886), p. 17). It belongs to the section *Leptospora* of *Lasiosphaeria.*

Bertia moriformis (Tode) de Not. in Giorn. Botan. Ital. I (1844), p. 335.

Specimens from Mulgrave Wood, communicated by the late Charles Crossland, otherwise typical, proved to have hyaline spores, at first 1-septate, finally 3–7-septate, 48–52 × 5–6 μ. Some of these spores were seen germinating from every cell. I have examined numberless other specimens but none had spores more than 1-septate. The spores are rather large for the species. I have not found 1-septate spores more than 46 μ long, still they most probably represent the mature state of *Bertia moriformis.* I am not aware that these multiseptate spores have been previously noticed. The matter is worthy of further investigation.

B. collapsa Rommell in Bot. Notiser (1892), p. 178.

This is certainly only a corrugated form of *Melanopsamma pomiformis* Sacc., as an examination of Rommell's specimen at Kew proved. The mature spores are pale brown. Marquand's material from the Channel Islands (Trans. Brit. Myc. Soc. I (1897), p. 24) is the same.

Rosellinia papaverea (B. and Br.) Ces. et de Not. in Comment. Crittogam. Ital. (1863), p. 228. *Sphaeria papaverea* B. and Br. in Ann. Mag. Nat. Hist., Ser. II, VII (1851), p. 188, t. 7, f. 14 (Notices No. 612).

An examination of a Batheaston specimen at Kew showed the perithecia to be ½ mm. across, covered, except the papilla, with a whitish felt (which may be adventitious) and seated on

a purplish-brown subiculum. The asci are 100–110 × 7–8 μ. The brown spores are straight or slightly bent, 10–11 × 5 μ. The ostiola are very remarkable and just as described by Berkeley and Broome. The contents of the perithecia may be seen being ejected through the pores as short tendrils. I am not aware that this species has again been recorded either in this country or abroad.

**Ceratosphaeria rhenana* (Auersw.) Wint. in Rabenhorst's Krypt-Fl. I. 2 (1885), p. 257. *Gnomonia rhenana* Auerswald in Gonn. and Rabenh. Myc. europ. V and VI (1869), p. 23.

Lytchett Matravers, Dorset. Not infrequent.

**Didymosphaeria vexata* (Sacc.) Wint. *l.c.* p. 422. *Didymella vexata* Sacc. in Mich. II (1880), p. 58.

On twigs of *Cornus*, Lytchett Matravers, Dec. 1921. The ovate subsessile asci and septate paraphyses are very noticeable. The epidermis was not perceptibly blackened. It is possible that *D. trivialis* (B. and Br.) Sacc. recorded from Batheaston and on *Cornus* (see Massee, in Grevillea XVIII (1889), p. 11) may prove identical.

Anthostoma amoenum (Nke.) Sacc. Syll. I (1882), p. 307. *Fuckelia amoena* Nke. in Fuckel Symb. Mycol. (1869), p. 224. *A. rhenanum* (Fuck.) Sacc.

Von Höhnel in Ann. Myc. XVI (1918), p. 122, definitely regards this species as synonymous with *A. rhenanum* (Fuck.) Sacc. Schroeter in Krypt-Fl. Schles. III. 2, p. 434, had suspected this. Winter in Rabenhorst's Krypt-Fl. II. p. 760, had described the spores as inaequilateral and bean-shaped, but this seems an error or exceptional and neither Schroeter nor von Höhnel mention it. The spores in my specimen were quite straight, broad and oblong, rather abruptly attenuate towards the ends, more towards the lower end and with the upper provided with a small obtuse hyaline knob. No hyaline envelope was evident all round but the knob is very persistent. It was absent however in some ejected spores. The valsiform nature of the pseudostromata is very evident. The upper surface of the cortex is blackened but no circumscribing black line was seen. It is recorded on *Acer* and *Fagus* by Winter, on *Fagus* by Schroeter and on *Carpinus* by von Höhnel. My specimens were on oak, near Bassenthwaite, Cumberland, Sept. 1922.

**Valsa Pini* (A. and S.) Fr. Summa veg. Scand. (1849), p. 412. *Sphaeria Pini* A. and S. Consp. (1805), p. 20.

On small branches of *Pinus sylvestris*. High Hurstwood, Sussex, February, 1912. Differs from *V. Abietis* Fr. in the more numerous perithecia. The spores were 10–12 × 2–2·5 μ. They are given as 6–9 × 1·5 μ by Winter, *l.c.* p. 709, though Berlese

and Bresadola (Micromyc. Trident. (1889), p. 10) give 10–11 × 2 μ for their forma *divergens*.

**V. horrida* Nke. Pyr. Germ. (1870), p. 176.

On birch poles, Sussex, Dec. 1911.

**V. germanica* Nke. *l.c.* p. 215.

On birch, Sussex, Jan. 1912. Appears to be constantly distinct from *V. ambiens* in its smaller spores 10–15 × 3–4 μ.

V. decorticans Fr. Summa veg. Scand. (1849), p. 412.

On hornbeam, Epping Forest, March 1910. On beech, Keswick, Sept. 1922. The spores of the specimens on hornbeam were only 10 × 2 μ as compared with 10–13 × 2·5 μ on beech, but they appear to belong to one species and to be distinct from any form of *V. ceratophora* Tul.

**Diaporthe Malbranchei* Sacc. in Mich. I (1879), p. 509.

On elm, Hove, Sussex, Nov. 1910. Only definitely distinct from *D. Eres* Nke. in its scarcely exserted ostiola.

D. resecans Nke. Pyr. Germ. (1870), p. 314.

Occurred at High Hurstwood, Sussex, both on *Syringa* and *Forsythia*, the two gatherings being quite indistinguishable.

**D. retecta* Fuck. and Nke. in Fung. rhen. No. 1992.

On box, Tumby, Lincolnshire, 1921.

D. controversa (Desm.) Nke. in Fuck. Symb. Myc. Nachtr. I (1871), p. 319. *Sphaeria controversa* Desm. in Ann. Sci. Nat. Ser. II, XVII (1842), p. 102.

Taking Winter's diagnosis of Desmazières' plant it is the common *Diaporthe* on ash in England and *D. obscurans* Sacc. does not seem separable. It is decidedly variable, the black line sometimes penetrating the wood deeply, sometimes not at all. The perithecia are sometimes with base immersed in the wood, sometimes wholly corticolous. The ostiola, however, are always short, thus distinguishing it from *D. scobina* Nke. A *Diaporthe* that I have found on *Ligustrum* seems indistinguishable but is, I suspect, *Diaporthe* (*Euporthe*) *ligustrina* Ell. and Everh. Though the sections *Euporthe* and *Tetrastaga* are convenient, no sharp line divides them, as experience in the field soon proves. Personally I consider *D. controversa* to occur on both *Fraxinus* and *Ligustrum*, even if *D. ligustrina* Ell. and Everh. and *D. Ligustri-vulgaris* Petrak are distinct species.

**D. patria* Spegazz. in Atti Soc. Crittogam. Ital. III. (1881), p. 53. *D. sorbicola* (Nke.) Schroet. in Krypt-Fl. Schles. III. 2 (1897), p. 428.

On *Pyrus Aucuparia*, Keswick, Sept. 1922. The spores were 16–20 × 4–5 μ, larger than those described by Schroeter and by Traverso.

**Coronophora angustata* Fuck. in Fung. rhen. No. 1854.

On beech, Lytchett Matravers, Dorset, April, 1922. This fungus is close to *C. gregaria* Fuck. but has much smaller spores. The peculiarities of the fructification of this species are described by Petrak in Ann. Myc. XIX (1921), p. 182. He thinks the manner in which the asci are evolved affords support to the correctness of von Höhnel in creating a family Coronophoreae.

BARK CANKER DISEASE OF APPLE TREES CAUSED BY MYXOSPORIUM CORTICOLUM EDGERT.

With Plates IX–XI and 3 Diagrams in text.

By Grace G. Gilchrist, B.Sc.

Introduction.

At Long Ashton in 1920, a disease was noticed in a plantation of bush apple trees doing very severe damage to the branches. In some cases, only one branch was affected, in others four or five branches were attacked and in others the disease had reached the crown of the main trunk and the trees were doomed. A character of the disease was the formation of large longitudinal scars on the sides of the branches and this symptom, together with the occurrence of numerous pustules of spores of the fungus *Myxosporium corticolum* Edgert., led to the identification of the disease as bark canker. Hitherto this disease had not been reported in this country although it has been known in the United States for some years.

Historical Notes.

In 1908 Edgerton (1) briefly described the bark canker as being produced by a new species of *Myxosporium,* which he named *Myxosporium corticolum.* He found the fungus to be perennial, living from year to year in the bark and forming a new ring of growth each year. The description which he gives of the appearance of the disease agrees closely with the symptoms observed at Long Ashton and which are described in detail later. The spore pustules were small, about 1–2 mm. in diameter, slightly raised at the place where the bark was ruptured. The spores were observed to ooze out of the pustules in white tendrils, but they readily separated in water. He described

them as long, cylindrical, hyaline, perfectly characteristic of the genus *Myxosporium.*

In nutrient solution, the spores germinated readily, a germ tube being put out during the first day, generally near one end of the spore. During the second day the spores usually became 1–3-septate and of a decidedly brownish tinge and later other germ tubes developed. After germination the mycelium grew very slowly, only producing a colony about 3 mm. in diameter in two weeks. Edgerton did not succeed in obtaining spores in artificial culture.

Lewis (2) in 1912 isolated the species from diseased apple branches. He transferred the fungus from plates to bean pods where it fruited and produced spores identical in shape and size with those from pustules on apple branches. Inoculation experiments which were carried out were not satisfactory and Lewis came to the conclusion that *Myxosporium* is not the sole cause of the killing back but that it attacks weakened branches, hastening their death and giving the appearance that they had been killed by a more active parasite than this fungus seems to be.

Stewart, Rolfs and Hall (3) in 1900 referred to this fungus as *Macrophoma Malorum* (Berk.) Berl. and Vogl. The opinion had previously been advanced that *Macrophoma Malorum* was an immature stage of *Sphaeropsis Malorum* Peck, but Stewart and his associates believe that the two forms are distinct. Subsequently (1910) Stewart accepted Edgerton's (1) name.

Hesler and Whetzel (4) in 1917 included a brief description of the disease in their Manual of Fruit Diseases. They state that the fungus is confined to the cortex, and that the originally infected areas are small and more or less circular, but larger cankers of various shapes finally appear as the result of the coalescence of two or more cankers, but that the fungus is responsible for such slight damage that it is very doubtful whether any sort of remedial measures are ever necessary or profitable.

General appearance of the disease.

The most characteristic feature of the bark canker disease is the extremely long narrow scars which it produces. These may run for a length of two or three feet down one side of a stem and not reach a breadth of more than 1½ inches. The disease may start at the top of one of the main branches and grow downwards, or it may develop from the soil level infecting the trunk and causing the rapid death of the tree. The dead area of the scar is somewhat sunken below the surrounding tissue owing to lack of new growth. The edges of the scar are usually

well defined by a rather deep crack and sometimes the formation of a callus round the healthy regions is noticeable during the summer. Pl. IX, fig. 1, represents a scar as it occurs in the middle of a branch although usually a scar of this sort is associated with a dead truss. Pl. IX, figs. 2, 3 and 4, are of a branch which became infected at the top, the disease progressing downwards. One occasionally finds scars which have become completely healed over by the growth of wound wood formed by a cambium at the edge of the scar (Pl. IX, fig. 5). Normally, however, this is prevented by the growth of the fungus.

The dead tissue is usually found covered with innumerable small fructifications scattered over its surface. Under normal conditions only the openings of the fructifications can be seen, but after a damp foggy night the spores accumulate at the openings and can be recognised as small white points (Pl. IX, fig. 6). After a shower of rain the spores are washed away and are no longer visible to the naked eye.

A rather unusual feature of this disease is the seasonal activity of the fungus. At only one period of the year do the scars increase, usually towards the end of summer, but this varies according to the season. In 1920, at Long Ashton, they started growth in October. In 1921, a much earlier ripening year than 1920, they started in August; whilst in 1922—a late season—the very first signs of the extension of the scars were visible on July 19th, but it was not until September that the fungus was really active. After a comparatively short period during which time the scars extend rapidly, the fungus becomes quiescent and remains so until the following year when it once more bursts into new growth. The interesting point is that although the fungus is always present, and presumably ready to grow, yet it is only at one period during the annual cycle that it can do so. The cause of this is obscure, but one cannot help thinking that the physiological condition of the tree, or perhaps of the fungus, or possibly of both, alters during the time when growth of the fungus is just taking place. The first sign of any activity on the part of the parasite is the appearance of faint cracks in the bark some little distance below a scar (Pl. IX, fig. 4). These cracks, which at first may be entirely dissociated from any previous crack, become more distinct in a few days and finally link up to form a well-defined line of demarcation at the edge of the bark canker, between the healthy and what subsequently becomes diseased tissue. The tissue within the crack browns and dies off, producing, after some little delay, the usual fructifications. The rapidity with which the fungus advances, once it has started into activity, is rather striking. With the canker produced by *Nectria galligena* and *Monilia cinerea*, the host

plant limits the progress of the fungus by the formation of successive cork layers, not very far distant from each other. In the present case, however, the cork layer is formed at very great distances from the old ones, sometimes 5 or 6 inches, or even more. A scar may progress longitudinally as much as 18 inches at a single step, although in a transverse direction it rarely exceeds ½ inch.

The opinion of American workers appears to be that the fungus is confined to the cortex and that the damage resulting from it is negligible. That may be so under American conditions, but in the case of the two outbreaks which have been recorded in England severe damage was being caused. It may be that the fungus becomes virulent when the trees are in a starved condition, but once it gets a firm hold on a plantation it may cause the loss of many trees. Not only the cortex is affected but also a large part of the woody tissues.

Description of the fungus.

1. *Appearance of fungus in tissues.*

The hyphae of *Myxosporium corticolum* are hyaline and vary greatly in thickness from 1μ to $3{\cdot}4\mu$. The mycelium is mostly confined to the cortex and at first does not penetrate far into the wood, but later penetrates as deeply as the wood of the second year. It grows freely in the dead tissue and is very abundant in the cortex and outer phloem. It is found chiefly in the air spaces of the cortex, but also in the cells themselves. In the wood the hyphae are confined almost entirely to the vessels and pass from one vessel to another through the pits (Pl. XI, figs. 13, 14 and 15).

2. *Distribution of mycelium in a mature canker.*

In its first stages the bark canker disease is essentially a bark disease but eventually the remaining part of the stem also becomes infected. Fig. 10 is a photograph of the diseased branch shown in Pl. IX, figs. 2, 3 and 4, cut transversely at distances 4 cms. apart arranged in rows from below upwards. In the lowest section (row 1) the only sign of disease was the presence of two cracks in the cortex, which were evidently the cracks where the scar was extending and which are very clearly marked in fig. 4. In the second section, the cracks were more prominent but the tissue between them was not discoloured. The fourth section showed dead tissue between the cracks, although such tissue was almost confined to the cortex, and of course represented the dead tissue of the old scar which had been killed long ago. The other sections revealed the presence of the scar

in the cortex. The wood finally became more and more diseased until the whole tissue was killed. Examining these sections microscopically fungal hyphae were not found in those of the first row although the fourth and fifth showed the wound reactions of the cortex and dark portions in the wood due to wound gum. The remainder of the sections (rows 2, 3, and 4) represent the older diseased parts. All these were heavily infected by fungal hyphae and wound gum was formed in large quantities in the wood vessels and in the thick walled wood parenchyma but not in the medullary rays, the phloem, or the cortex. Thus it is evident that wound reactions of the cortex and the formation of wound gum takes place much in advance of penetration by mycelium.

3. *Method of advance of the mycelium.*

The microscopic details of the way in which the mycelium advances in the tissues are interesting. As described above the sudden appearance of cracks in the bark denotes the extension of the scar and if a transverse section is taken at such a level, nothing abnormal can be seen in the cortex except the deep cracks, usually two, which mark the area to be infected. A slight tendency of the tissues limited by these cracks to redden more rapidly than the normal cortex is sometimes observed. The cracks are usually almost radial and extend somewhat deeply into the cortex, almost if not quite, reaching the wood. Further toward the old infection, long zones of browned tissue are sometimes formed in the phloem region. These zones may extend tangentially (i.e. parallel to the circumference and concentric) for considerable lengths, isolated portions of brown tissue joining up laterally but never radially. There may be one, two or even three of them running parallel to each other but quite disconnected. They consist of dead tissue and may reach a thickness of 100–140 μ separated by rings of normal phloem about 150 μ in width. The cell walls of the normal phloem measure about 1·5 μ thick, but in the browned zones they are swollen to 3 to 4·5 μ in thickness. Occasionally the cell contents in the affected area are turned brown and coagulated, and the portion of a medullary ray which may sometimes be found passing through the dead tissue is usually similarly affected. In the phloem, between the concentric browned zones, large numbers of crystals occur which physical and chemical tests show to be calcium oxalate (Pl. IX, figs. 8 *a*, *b* and *c*).

The occurrence of these zones is not invariably associated with bark canker, but they have been found in a number of cases so that they appear to be caused by *Myxosporium corticolum.*

No hyphae are found in the browned zones at first but as one follows them back to the older infected parts the extent of the browned zones increases, the cortex dies, wound gum appears in the wood, and finally mycelium gradually becomes visible as has been described above.

4. *Description of conidia and their measurement.*

The majority of the conidia are oval or slightly allantoid in shape, although occasionally they are found to be quite curved, with the result that at one time this fungus was thought to be *Macrophoma curvispora* Peck. The end of the conidium nearest the conidiophore is somewhat bluntly pointed, while the other end is conspicuously rounded. The cell wall is comparatively thick. These conidia are unicellular, hyaline, and contain large refractive globules varying from 1 to 3·5 μ in diameter. The latter are stained brown with osmic acid, and distinctly pink with Millon's reagent and are therefore probably proteid in character. The conidia vary in length from 25 to 45 μ and in width from 9 to 18 μ.

5. *Description of development of the fructification.*

When the fungus is about to produce fructifications, the mycelium at various points just below the epidermis forms small stromatic masses. The epidermal layers are thus raised in the shape of a dome, the covering of which still remains unbroken. The hyphae in the centre of the stroma now begin to elongate perpendicularly to the epidermis and develop into a definite column of tissue, which forces the epidermis out 300–350 μ. The hyphae round the base of the central column do not increase their rate of growth but form a kind of basal disc (Pl. XI, figs. 17 *a*, *b*, *c*). The spores are produced in large numbers from the hyphae on this disc. A hypha becomes constricted immediately below its apex, forming a small oval-shaped portion. Protein material passes from the hypha into this portion which increases in size until it becomes, on an average, 36 μ by 12 μ. Eventually this portion, which is a conidium, is cut off at the point of constriction and the hypha is ready to form more conidia in a similar manner (Pl. XI, fig. 17 *f*). The epidermis remains unbroken until the conidia are ripe. The sterile hyphae of the central column then grow until the layers of bark break. At first only a narrow opening is formed, but as the whole of the fructification grows, the slit widens and the bark is pushed outwards. The conidia are shed into the space between the stroma and the bark. Under suitable conditions of warmth and moisture these are pushed out of the opening in such numbers

as to be visible to the naked eye as white points (Pl. XI, figs. 17 *d, e*). No other form of fructification has been discovered.

Cultural Studies.

I. *General growth on different media.*

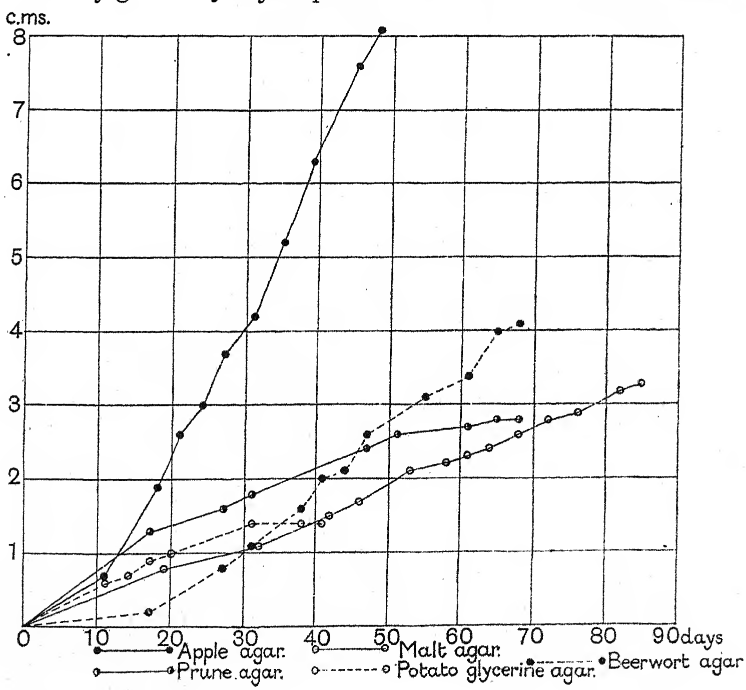
Pure cultural studies of *Myxosporium corticolum* have been made on various media. The characteristic growth of the mycelium, its effect on the medium and any other points of interest are set forth in the following table:

Medium	Effect on colour of medium	Colour of mycelium	Formation of mycelium
Apple twig	— —	White	Hyphae very well developed both on cut surface and where they have burst through the bark. Numerous large drops of amber-coloured to dark-brown liquid. Conidia
Pear twig	— —	Brown and white	Fibrous and not so well developed as on apple twig. Small quantity of amber-coloured liquid
Cherry gelatine	Changed from yellow to dark brown	White on slope culture. White and brown on roll culture	Good growth of flocculent hyphae. No amber-coloured liquid
Cherry agar	Changed from yellow to red	White on slope culture. White, yellow and green on roll culture	Flocculent hyphae, not so well grown as on cherry gelatine. No amber-coloured liquid. Slight formation of concentric rings when grown on a roll culture
Rice	Changed from white to purple-brown	White	Flocculent hyphae, surrounding each grain of rice
Potato stem	— —	White	Inconspicuous growth
Apple fruit	— —	White and grey	Fibrous and flocculent. A few drops of brown liquid
Carrot	Changed from orange to red-brown	White and whitish pink	Good growth. Drops of brown liquid
Maize	From yellow to brown	White	Flocculent hyphae
Cellulose agar	— —	White	Poor growth, thin film of very fine hyphae on surface of medium
Malt agar	From yellowish grey to brown	White	Moderate growth. Large number of small drops of brown liquid formed. Cracks appear in the medium which increase in size and number with age. Conidia are formed in small cream pustules looking like drops of emulsion. Later dark green sclerotia are formed containing conidia
Prune agar	— —	White	Moderate growth. No drops of liquid formed
Apple agar	Crimson in centre of colony, surrounded by band of dark green, edge yellow	White	Flocculent growth. No drops of liquid

Medium	Effect on colour of medium	Colour of mycelium	Formation of mycelium
Beef peptone agar	— —	White	Centre of colony fibrous, edge smooth and forming a thin film on the surface
Potato glycerine agar	— —	Old portions brown, young portions white	Practically all the growth is under the surface of the medium, in the form of a solid mass. No drops of liquid
Apple juice	— —	Orange	Good growth, solidifying the liquid
Beerwort agar	Slightly darkened	White	Very large drops of light brown liquid
Prune juice	— —	Light brown	Moderate growth
Uschinsky's solution	— —	White	Poor growth

In the above table it will be seen that grown on certain media the hyphae secrete yellowish and brown viscid drops. In view of the abundance of crystals of calcium oxalate in cultures of the fungus on agar media, this liquid was tested and found to contain oxalic acid. The variations of growth on different media are very great; apple twigs, apple agar, and apple juice are very good media but the fungus prefers gelatine to agar. On no cultures were chlamydospores found and the colonies showed a marked absence of rings. The rates of growth are shown in the following graph:

Rate of growth of Myxosporium corticolum *on various media.*



2. *Temperature relations.*

In order to obtain some information regarding the thermal relations of this fungus, a number of slope cultures were made on malt extract agar and incubated at the temperatures given in the following table. The size of the resulting colonies after six weeks' growth are recorded. It appears that the optimum temperature for growth is about 15° C., the maximum temperature between 25° and 30° C. and the minimum temperature between 0° and 1° C.

	Temperature	Measurement of colonies after 6 weeks' growth, cm.
1.	Cold storage (0°–1° C.)	1·3 × 1
2	Incubator (15° C.)	5·2 × 2
3.	Cupboard in laboratory (15° C. in daytime, less at night)	4·2 × 2
4.	25° C. incubator	3·3 × 1·8
5.	30° C. incubator	nil
6.	35° C. incubator	nil

3. *Production of conidia in pure culture.*

Conidia have been produced in pure culture on sterile apple twigs and on malt agar slopes. Those produced on sterile apple twigs are formed as in nature. In pure cultures of malt agar slopes the process is somewhat different. After four months' growth, dark green irregular roundish bodies were noticed (Pl. X, fig. 9). On examination these proved to be little masses of stromatic tissue where the hyphae were twisted together to form a kind of sclerotium. Sections through these bodies showed that they contained large numbers of conidia. Pethybridge (5) mentions a similar occurrence in *Colletotrichum Tabificum* (Hallier) Pethybr., a fungus closely related to *Myxosporium*. In *Colletotrichum* this is the only form of fructification and the sclerotia-like bodies are found on dead or dying potato stalks, especially on the parts below ground. So far no corresponding bodies have been found in nature in connection with *Myxosporium corticolum*.

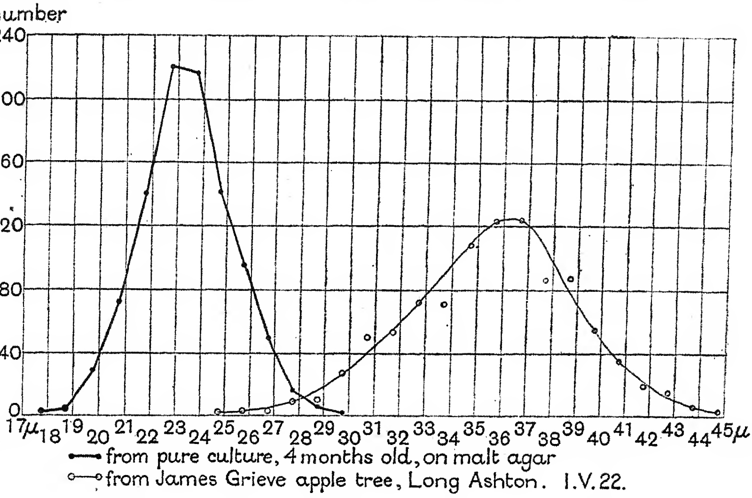
4. *Difference of conidial measurements from those occurring in nature.*

A careful study of spore measurement has been made both of spores from the apple branch and from those produced in pure culture.

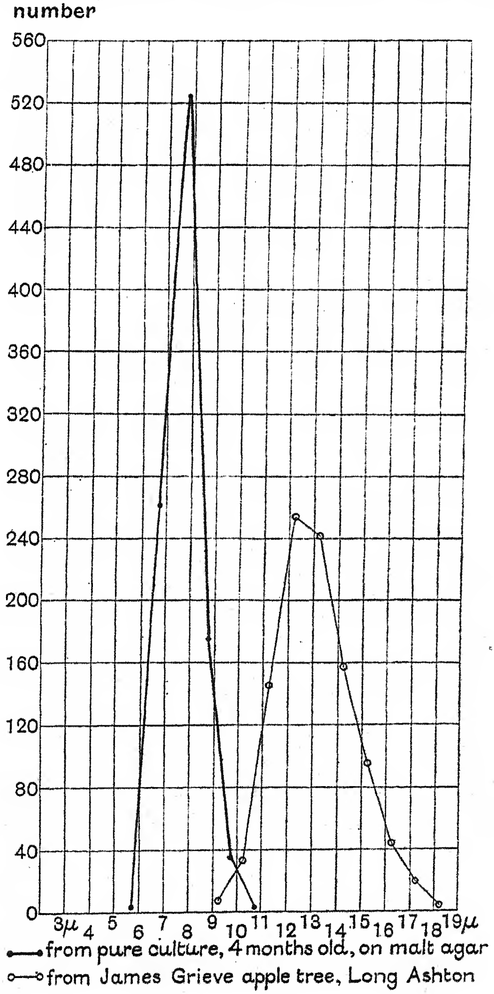
Fresh material was collected in May 1922 from the variety James Grieve and 1000 spores measured. They varied in length from 25–45 μ, the largest number being 36 μ in length. The width varied from 9–18 μ, the majority being 12 μ in width.

The spores developed in pure culture were distinctly smaller. This observation disagrees with that made by Lewis (2), who,

Length of Spores of Myxosporium corticolum.



Width of Spores of Myxosporium corticolum.



in a pure culture grown on bean pods, obtained spores of the same size as those produced on apple branches. Measurements were made of 1000 conidia from a pure culture grown on malt agar. Here the length varied from 17·5 μ to 29·5 μ, the majority being 25 μ in length, and the width varied from 6 to 10·5 μ, the majority being 7·5 μ in width.

The graphs on p. 239 give the frequency curves for conidia produced naturally and artificially.

5. *Germination of conidia.*

The conidia germinate very readily even in distilled water, and the germination of single spores was followed in a number of cases. In Pl. X, fig. 12 (*a*) represents a conidium from a hanging drop culture in a dilute solution of malt extract. It remained on a bench in the laboratory at about a temperature of 15° C. during the daytime and slightly less at night. In 16 hours a germ tube had been put out from one side, nearer the round end than the pointed end of the spore. When the culture was 48 hours old, this germ tube had grown considerably, becoming septate and branched, while a cross wall had formed in the spore dividing it into two cells approximately equal in size. When four days old, the spore was found to have put out a second germ tube which arose from the other end of the spore, that is, the pointed end. Each of these germ tubes grew and branched giving rise to the colony shown in Pl. X, fig. 12 (*h*). Observations of other germinating spores showed that the procedure described above approximates the normal. The first germ tube may arise from either end of the spore and is usually initiated before the spore divides into two cells. The second germ tube is developed from the second cell and therefore from the opposite end of the spore within about three days.

INOCULATIONS.

The association of *Myxosporium corticolum* Edgert. with the bark canker disease has been recorded by four sets of observers previously and it seems extremely probable that it is responsible for the disease. Lewis (2) only, however, has obtained a successful infection from an artificial inoculation. "On one branch inoculated with *Myxosporium* the typical killing back which is characteristic of branches on which this fungus so frequently occurs was found. Other branches failed to show any injury whatever due to the inoculations." The exact number of inoculations was not recorded but seventeen are definitely mentioned.

The total number of inoculations made at Long Ashton amount to 45, but so far no definite signs of successful infection

have resulted. The methods of inoculation have been varied so as to obtain the conditions thought to be most likely for success. The method which gave most promise was the injection of a spore suspension by means of a hypodermic syringe. These inoculations, however, at six months only show very small scars about 5 mm. in diameter.

The results from these experiments support the views of the American authors that the fungus is only a weak parasite and only under exceptional conditions does it become dangerous. When these conditions are reached, however, much permanent damage is done to the trees and they may be killed outright.

Method of infection in nature.

Trees which are being attacked by *Myxosporium corticolum* are usually in a weak state and dead spurs are not infrequent (Pl. IX, figs. 2, 5 *a*). On such dead spurs the fructifications of the fungus have frequently been observed and possibly entrance to the tree is gained by this means. Occasionally a fungus with a much smaller spore ($9\mu \times 3\mu$) and resembling *Myxosporium Mali* Bres. has been found on apple branches, but it is quite distinct from *Myxosporium corticolum*. This is interesting in view of the observations recorded by Marchal (6) who obtains considerable variations in the character of *Fusicoccum Malorum* Oud. in culture, especially as regards the dimensions of the perithecial necks and the grouping of the perithecia. So much so that it seems possible that several forms, *Aposphaeria Pomi* Sacc. and Schulze, and *Myxosporium Mali* Bres., are merely variations of *Fusicoccum Malorum* Oud. *Diaporthe perniciosa* March. hibernated on the branches of pear and apple, producing a canker in the outer layers of the bark. The bark infections give rise to numerous pycnidial stromata in the autumn which remain hidden in the external layers, thus simulating certain species of *Myxosporium*.

Another method by which infection takes place is through grafting-wounds. In a nursery at Sandford in Somerset a number of young standard trees were found to be infected with *Myxosporium corticolum*, the fungus evidently had entered through the exposed surface of the stock, the saddle type of grafting having been used. Pl. IX, fig. 7, shows a photograph of a specimen obtained from this source.

Occasionally also, one finds trees which had evidently become infected from the base. Usually other fungi are present in such abundance that it is impossible to identify the original parasite. Recently, however, a ten year old bush tree of the Lord Suffield variety died off very suddenly during July and close examination of the main trunk showed the typical fructifications of

Myxosporium corticolum in enormous numbers. The method by which the fungus enters the tree in this case can only be conjectured, but it evidently came from the region of the ground.

SUMMARY.

1. *Myxosporium corticolum* Edgert. is the cause of bark canker disease.

2. A characteristic of the disease is the formation of large longitudinal scars on the sides of branches, on the dead tissue of which numerous acervuli are found.

3. The scars increase rapidly at one period of the year only, usually towards the end of the summer.

4. The fungus is most abundant in the cortex, but also occurs in the phloem, and the wood.

5. In the wood infected by the hyphae wound gum is formed in large quantities in the wood vessels and in the thick walled wood parenchyma, but not in the medullary rays, the phloem, or the cortex.

6. Wound gum is formed in advance of the hyphae.

7. Conidia are produced in acervuli; they are oval or slightly allantoid in shape and measure $25–45\,\mu \times 9–18\,\mu$. They germinate easily.

8. In pure culture hyphae grow very slowly, preferring gelatine to agar. On certain media the hyphae secrete drops of brown liquid which contain oxalic acid. Crystals of calcium oxalate are invariably found in the media on which *Myxosporium corticolum* has been growing.

9. In pure culture conidia have only been formed on apple twigs and 2 % malt agar. In the latter case they are formed inside a dark green body, in appearance like a sclerotium.

10. As a result of inoculations, *Myxosporium corticolum* seems to be a weak parasite except under certain conditions. When these conditions are reached, however, much permanent damage is done to the trees and they may be killed outright.

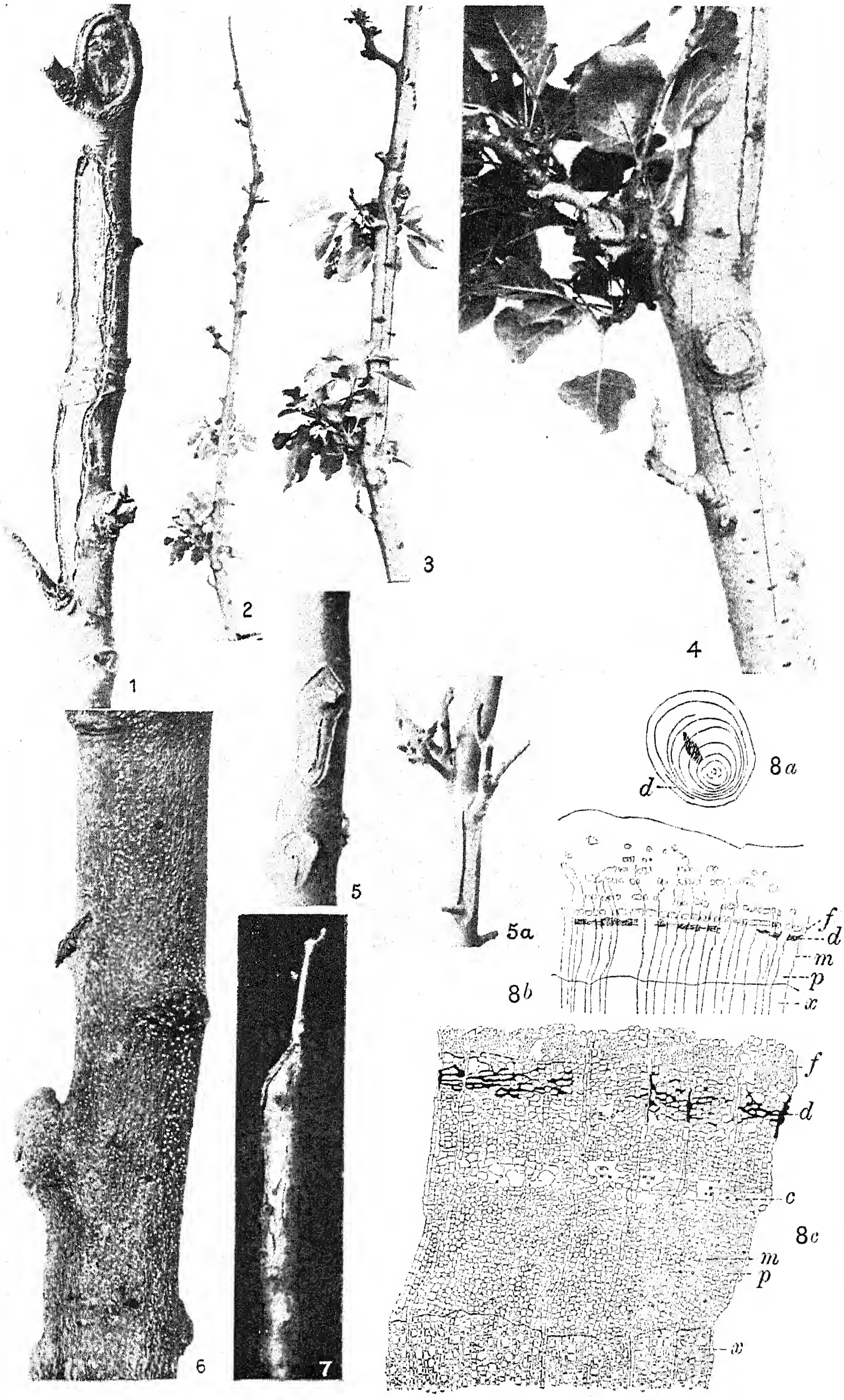
11. The fungus in some cases enters through a dead spur; in other cases infection comes from the region of the ground. Infection may also take place through grafting wounds.

I take this opportunity of thanking Mr S. P. Wiltshire who originally suggested this investigation, and also provided material, and took an active interest throughout.

I also wish to thank Professor O. V. Darbishire and Professor B. T. P. Barker for their advice and interest in this work.

CRYPTOGAMIC RESEARCH LABORATORY,
THE UNIVERSITY,
BRISTOL.

November, 1922.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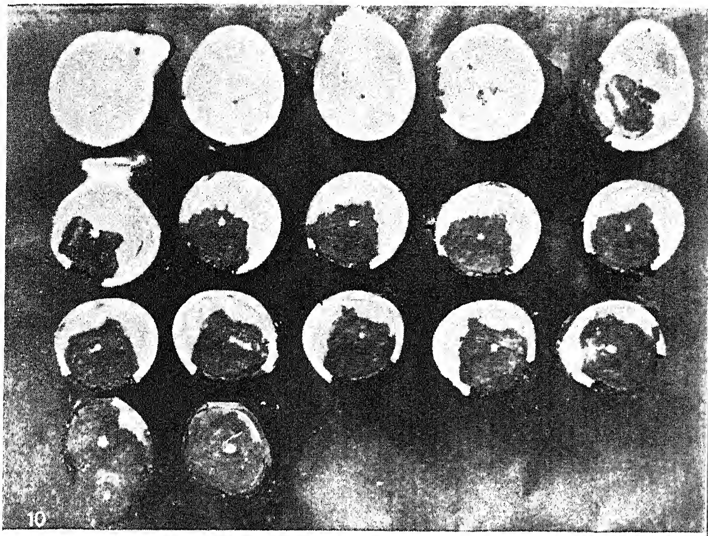

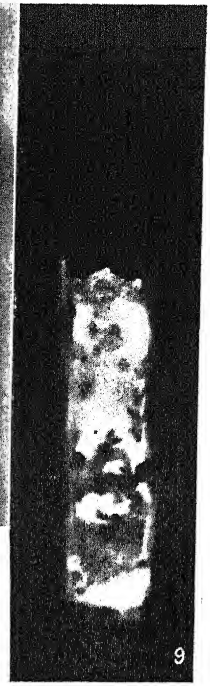

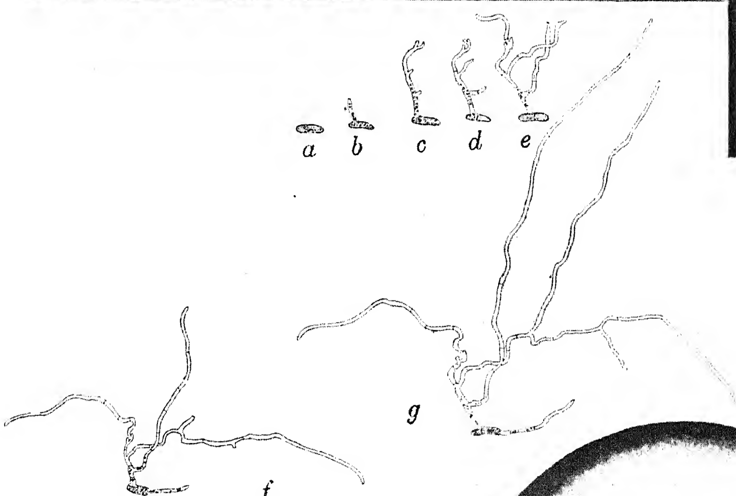

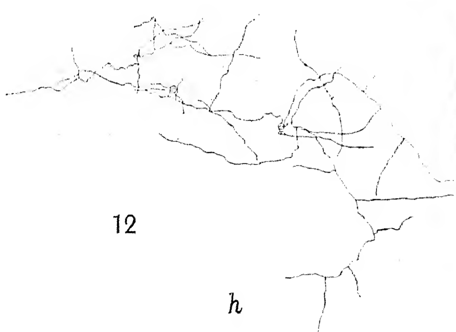

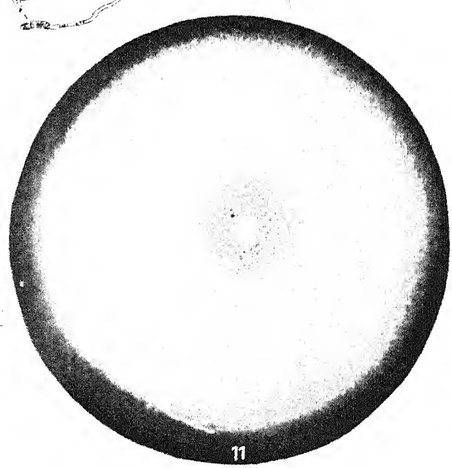

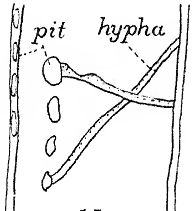

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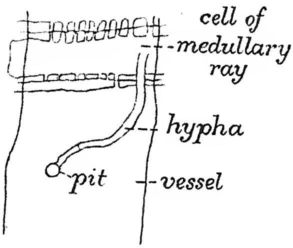

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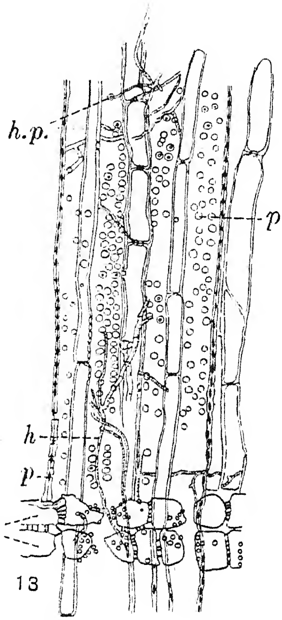

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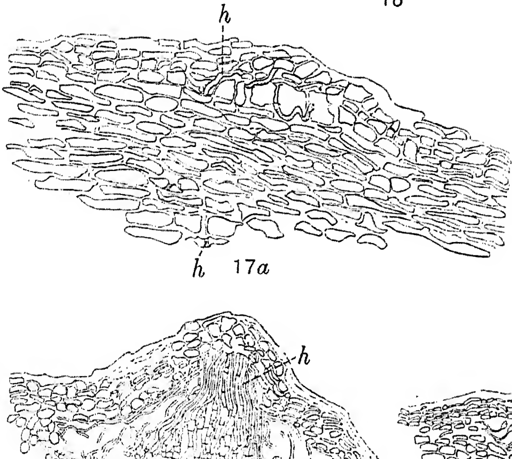

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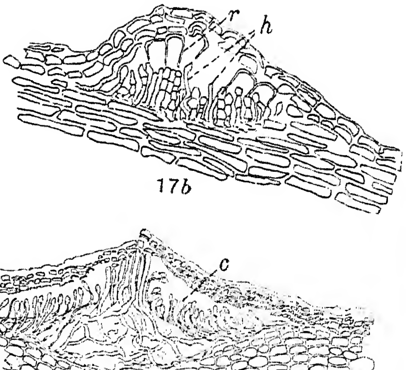

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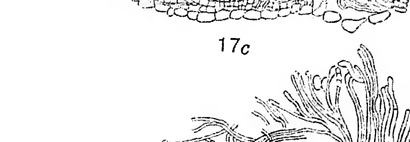

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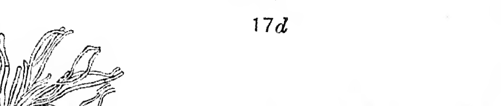

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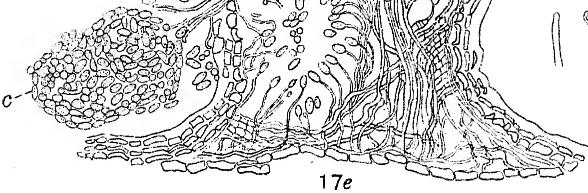

17*e*

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REFERENCES.

(1) Edgerton, C. W.—Two little known Myxosporiums. Ann. Mycol. vi, p. 48 (1908).

(2) Lewis, C. E.—Inoculation Experiments with fungi associated with apple leaf spot and canker. Phytopathology, ii, p. 49 (1912).

(3) Stewart, F. C., Rolfs, F. M. and Hall, F. H.—A Fruit Disease Survey of Western New York in 1900. New York Agric. Expt. Sta. Bull., No. 191, p. 298 (1900).

(4) Hesler, L. R. and Whetzel, H. H.—Manual of Fruit Diseases. New York, pp. 130–132 (1917).

(5) Pethybridge, G. H.—Notes on some saprophytic species of fungi, associated with diseased potato plants and tubers. Trans. Brit. Mycol. Soc. vi, p. 104 (1919).

(6) Marchal, Él. et Ém.—Contribution à l'étude des champignons fructicoles de Belgique. Bull. Soc. Roy. Bot. Belg. liv, p. 109 (1921).

DESCRIPTION OF PLATES.

Plate IX.

Fig. 1. Typical scar caused by *Myxosporium corticolum* Edgert. on apple tree, 5 November, 1920.

Fig. 2. Whole branch of James Grieve apple tree killed by *M. corticolum*, 24 August, 1921.

Fig. 3. Near view of same branch.

Fig. 4. Near view of same branch showing new scar forming.

Fig. 5. Scar caused by *M. corticolum* completely healed over by the growth of wound wood.

Fig. 5 *a*. Scar of *M. corticolum* with dead spurs.

Fig. 6. Pustules of *M. corticolum* on James Grieve, 29 October, 1920.

Fig. 7. *M. corticolum* on young standard apple tree, Sandford, Somerset, December, 1921.

Fig. 8. (*a*) Tr. section of apple branch showing line of dead tissue in phloem (*d*).
(*b*) Portion of above. × 10. *x* = xylem; *p* = phloem; *m* = medullary ray; *d* = dead tissue; *f* = fibres.
(*c*) Same. × 45. *c* = crystals of calcium oxalate.

Plate X.

Fig. 9. Streak culture of *M. corticolum* showing formation of spore masses on malt extract agar, January, 1922.

Fig. 10. Tr. sections (4 cm. thick) of branch shown in Figs. 2, 3, 4, 25 August, 1921.

Fig. 11. Plate culture of *M. corticolum* on prune extract agar, incubated at 20° C., four weeks old, 11 March, 1922.

Fig. 12. Germination of single spore of *M. corticolum*.

(*a*)	November 15,	11.30 a.m.	× 100.		(*e*)	November 18,	9.45 a.m.	× 100.
(*b*)	,, 16,	3.45 p.m.	× 100.		(*f*)	,, 19,	11.15 a.m.	× 100.
(*c*)	,, 17,	11.15 a.m.	× 100.		(*g*)	,, 20,	10 a.m.	× 100.
(*d*)	,, 17,	5.15 p.m.	× 100.		(*h*)	,, 22,	11.30 a.m.	× 10.

Plate XI.

Fig. 13. Mycelium of *M. corticolum* in the wood of apple. *h.p.* = hypha entering pit; *h* = hypha; *p* = pit; *m* = medullary ray. × 180.

Fig. 14. Long. section of wood vessel showing hypha passing into pit. × 420.

Fig. 15. Long. section of wood vessel. × 420.

Fig. 16. Spores of *M. corticolum* from James Grieve apple tree. × 260.

Fig. 17. (*a*) Tr. section of apple bark. 1st stage of acervulus. *h* = hypha. × 130.
(*b*) ,, ,, 2nd stage. *r* = stretched radial walls of bark. × 130.
(*c*) ,, ,, 3rd stage. × 100.
(*d*) ,, ,, 4th stage. *c* = conidium. × 90.
(*e*) ,, ,, 5th stage. × 100.
(*f*) Development of a conidium. × 390.

A NEW SPECIES OF SIGMOIDEOMYCES THAXTER.

With Plate XII.

By R. C. McLean.

In November 1921 a fungus was discovered growing on the surface of soil in a pot in the greenhouse attached to the Botanical Department, at University College, Cardiff, which proved to be a new species of *Sigmoideomyces* Thaxt., a genus of Mucedinaceae.

This genus has a curious history. The type species is *S. dispiroides* Thaxt., described from Burbank, E. Tennessee; habitat rotten wood. A second species was found by Mrs Bayliss Elliott at Birmingham and described by her under the name of *S. clathroides*. The present form makes a third species. The genus has therefore only been seen thrice, at widely separated stations and on each occasion in a different specific form.

The species under consideration was found on the soil in a pot in which seeds of *Impatiens sultani* had been sown about ten days previously. The soil was of the same blackish or sooty tinge, common in city gardens, as that on which the Birmingham specimens were found, giving a slightly acid reaction at about *p*H 6·0. It had not been long in the pot, but had been in use for potting purposes in the greenhouse for some time. The average temperature of the greenhouse during November is 65°–70° F. and it is neither very light nor very well ventilated.

As Mrs Bayliss Elliott connects the occurrence of her species with the presence of dead earthworms in the soil, I should say here that there did not appear to be any dead worms in the original pot of soil, though they may have disappeared by decay before I turned it out some time later; neither have attempts to recover it by enclosing samples of the soil, containing dead worms, in stoppered glass jars, been successful, though they have stood the full six months Mrs Bayliss Elliott found necessary for its development. This does not however disprove the interesting correlation which certainly appeared in her cultures. Attempts to obtain artificial cultures were unavailing, though several times repeated, owing to the abundance of bacteria both on and around the conidial fructifications. The wild growth disappeared after about six weeks and has not been seen since.

The naked-eye appearance of the fungus is that of a number of buff-coloured, fluffy balls, about 1 mm. in diameter and 2–3 mm. apart, dispersed in patches on the surface of the soil, the connecting, sterile mycelium being so fine as to be scarcely visible. These balls are the conidial fructifications, each com-

posed of a radiating mass of tapering, branched and apparently dichotomising hyphae, from which arise laterally the globose conidiophores on slender pedicels. The conidiophores are borne only on the stouter branches, towards the centre of the mass, so that they are protected by the sterile, apical portions of the hyphae. They arise in pairs, one on each side of the large cells which form the angles of the dichotomies.

The branching of the upper portions of the hyphae is strictly monopodial and in spite of appearances I am persuaded that it is so throughout and that the apparent dichotomy of the basal portions is due to secondary divergence of branches which are not in reality of equivalent rank. Reference to Pl. XII, fig. 5 will make this point clearer. Each conidiophore bears 25–30 short, conical sterigmata on each of which is one spherical, minutely echinulate conidium. The development of the conidium follows that of the conidiophore in point of time, being budded off when the latter has practically reached its full size. Both conidia and conidiophores are very caducous and the latter also readily collapsible, except perhaps when fully mature. The angle-cells, likewise, on which they are borne seem easily distorted by the leverage of the branches.

One curious feature, in which this species is peculiar, is the development of little prominences on the cells towards the apex of the filaments, easily seen with a low power and suggesting sterigmata, though no propagative bodies have ever been seen attached to them. High magnification on the other hand, reveals that each hypha bears a dense epiphytic flora of filamentous bacteria (*Leptothrix*?) which look exactly like flagellar appendages, particularly as one or more is regularly attached to each of the aforementioned prominences.

The vegetative mycelium, from which these perithecial-like balls of hyphae arise, is scanty and consists of long, unseptate filaments with an average diameter of 2–3 μ and very sparingly branched.

The claim of this new form to specific distinction rests on the following points:—(*a*) The rectilinear fertile hyphae, lacking that sigmoid curvature whence the genus takes its name. This is an important departure from the type, although in a character probably subject to environmental modification, but the *ensemble* of habit and structure undoubtedly points to its inclusion in the genus even though it should thus render the generic name no longer apt. That is not a matter on which too much stress need be laid for the validity of this or indeed of most genera does not rest on a single feature but properly on the syndrome of characters in the generic definition. (*b*) The rigidly divaricate and pseudo-dichotomous branching of the fertile hyphae. (*c*) The prominences on the apical portions of these hyphae.

(*d*) The smaller conidia with exosporic emergences, less prominent, however, than in the type species.

The present form, which I call *Sigmoideomyces divaricatus*, is notably more closely allied to Thaxter's American species than to the Birmingham one.

Mrs Bayliss Elliott raised the interesting question whether *Sigmoideomyces* was congeneric with *Gymnoascus*. The resemblance of these masses of fertile hyphae to the perithecia of that genus is certainly striking but the conidial and ascigerous forms have not been found in conjunction and the matter is still open. It must be admitted, however, that the Birmingham species, *S. clathroides*, is more like *Gymnoascus* than are either *S. dispiroides* or *S. divaricatus*.

SIGMOIDEOMYCES Thaxter, emend.

Fertile hyphae septate, loosely aggregated and either bent into many sigmoid curves or radiating from a common centre; branching sub-dichotomous, the ultimate branches sterile. Conidiophores vescicular, spherical, borne laterally on the hyphae by a stalk. Sterigmata short, spine-like, scattered. Conidia one-celled, spherical, echinulate or almost hyaline.

S. divaricatus n.sp. Fertile hyphae forming buff-coloured tufts about 1 mm. in diameter and 2–3 mm. apart; the hyphae rigid, radiating from a common centre, tapering, the ultimate branches freely divaricating and bearing laterally small, conical protruberances. The cells at the angles of dichotomy, in the inner part of the tuft, bear each two short, cylindrical outgrowths, in a plane at right angles to that of the branching, each terminating in a thin-walled, spherical conidiophore, 20 μ (15–25 μ) in diameter, upon which are borne the conidia 6–9 μ, minutely echinulate, hyaline. Sterile hyphae forming a scanty mycelium, each being about 2–3 μ in diameter.

On surface of soil in pot. Greenhouse: Botanical department: University College, Cardiff.

REFERENCES.

THAXTER, R.—On certain new and peculiar North American Hyphomycetes.... Bot Gazette, XVI, p. 14 (1891).

BAYLISS ELLIOTT.—Sigmoideomyces clathroides. A new species of fungus. Trans. Brit. Mycol. Soc. IV, p. 121 (1912).

EXPLANATION OF PLATE XII.

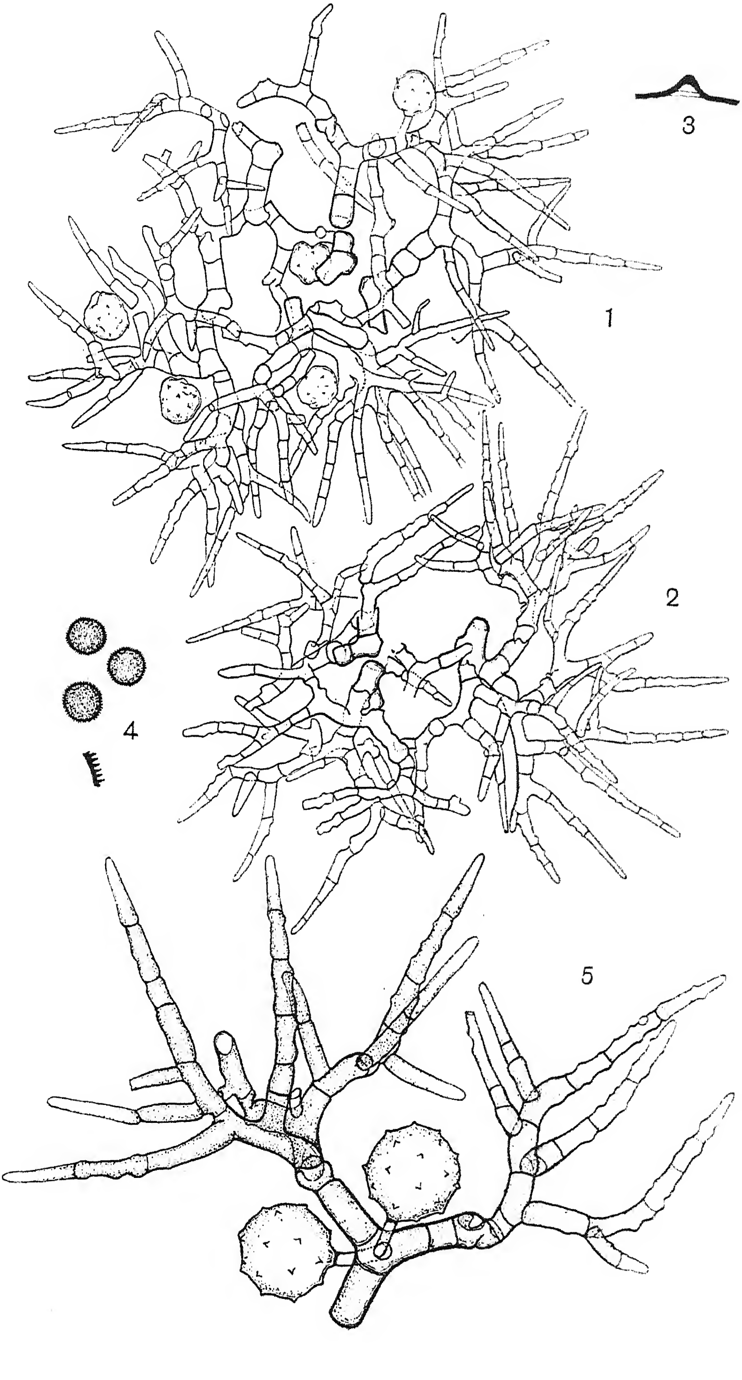
Fig. 1. *Sigmoideomyces divaricatus.* A small "perithecial" tuft of fertile hyphae, teased out, showing the conidiophores, from which the conidia are detached. × 200.

Fig. 2. Portion of an older tuft; the conidiophores having fallen off. × 200.

Fig. 3. A single sterigmaton. × 2000 ca.

Fig. 4. Conidia, and a portion of the conidial wall in section, showing the minute prominences. Conidia × 750.

Fig. 5. Fertile hyphae, illustrating the mode of branching and the attachment of the conidiophores. × 750.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WART DISEASE OF THE POTATO.

PRELIMINARY EXPERIMENTS.

By M. C. Potter, Sc.D., M.A., F.L.S.

For some time it has been recognised that certain plants are associated with acid and others with alkaline soils, and that soil acidity or alkalinity is a determining factor in the distribution of plants. Atkins has recently correlated the range of hydrogen ion concentration with the growth of over one hundred plants. In a similar manner it is found that micro-organisms are also sensitive to culture media. Potts showed in 1905 that the turnip disease known as Finger-and-Toe was absent from slightly alkaline soils; Jamieson and later Atkins have also noted that this disease is more prevalent in acid soils.

A series of experiments have been instituted in the Botanical Department of Armstrong College to determine the limits of hydrogen-ion concentration between which the potato can live and also to determine the *p*H range of *Synchytrium endobioticum,* the causal organism of wart disease.

The experiment consisted in growing a non-immune variety of potato in soils of varying *p*H concentration, and ordinary garden soil taken from an old allotment was employed for the purpose. In the previous year this soil had been infected with wart disease and a crop of badly infected potatoes grown upon it. It was therefore a soil in which wart disease would occur and was in every way suitable for the experiment.

The variations of soil alkalinity were brought about by the applications of different amounts of washing soda crystals and of chalk.

Large ten-inch flower pots filled with the treated soil were sunk in the ground out of doors and a seed potato was planted in each.

Controls. Two controls were taken; one of the original soil and the other of this soil specially mixed with wart diseased potatoes. The potatoes planted in both these pots gave rise to tubers infected with wart disease.

Washing soda. Six pots were used and to the soil in these pots was added respectively 14, 28, 56, 112, 168 and 244 grams of washing soda. The soda was dissolved in water and poured over the surface of the soil. Any water running through was caught in a porcelain pneumatic trough and poured over the surface again, this operation being repeated until the water was all absorbed by the soil. The soil from each pot was then separately turned out, thoroughly mixed, and replaced. The *p*H of the soil in these six pots was found to be approximately 8, 9, 9·5, 10, 10·5 and 11, the soil as taken from the garden being approximately 7·5.

The non-immune variety Up-to-Date was used and a single tuber planted in each pot, about the middle of April. The shoots from the potatoes appeared above ground in the usual time, except in the pots with 168 and 244 grams of soda. In the former of these the shoot from the germinating potato was somewhat later in pushing its way through the soil and in the latter the shoot failed to appear. The tuber when removed from the soil showed that the eyes had commenced to germinate but had failed to develop and had died off; the roots had also failed to penetrate the soil. This tuber was encouraged to germinate and was again planted in the same pot. Later in the summer, when the excessive rain had leached some of the soda from the soil, a very stunted growth was produced, with a few tubers ranging from the size of a pea to that of a bean. The old tuber did not decay in the soil. It may be assumed that the higher limit of soil alkalinity had been attained by the application of such a large quantity of soda.

The following table shows the *p*H concentration at the commencement and at the conclusion of the experiment and also the occurrence of the disease. It will be noted that the wart disease did not appear in the pot with 168 grams of soda.

Pots	*p*H concentration		
Grams of soda	Commencement	Conclusion	
14	8	7	Wart disease
28	9	7·5	,,
56	9·5	8	,,
112	10	8·5	,,
168	11·5	9·2	No wart disease

(168 grams on a ten inch pot would be approximately 2 ozs. per sq. yard.)

The diminution of the *p*H concentration would be due to the leaching action of the almost continuous rains during the summer of 1922.

A parallel experiment, neutralising the soil with chalk, was also carried out. Two pots were employed filled with soil similarly infected with wart disease, the one having $\frac{1}{8}$ chalk and the other $\frac{1}{4}$ chalk mixed with it. In the first the *p*H varied from 10 at the commencement to 9·5 at the conclusion and in the other pot the same variation was from 11 to 10. In neither of these pots was any wart disease to be discovered upon the tubers.

From these experiments it may be inferred that *Synchytrium endobioticum* is sensitive to a high degree of alkalinity and fails to attack the potato when the *p*H concentration of the soil is in the region of *p*H 10·5.

The experiment was not designed to form any idea of the influence of soil alkalinity upon the yield of tubers, but it may be remarked that soil alkalinity, while preventing wart disease, has a tendency to diminish the crop.

A plan has been set on foot to extend this line of enquiry during the coming year, repeating these experiments and extending them to other varieties of potatoes.

The problem of increasing the acidity of the soil has also been attacked and it is hoped to conduct experiments upon the relationship of soil acidity to wart disease.

REFERENCES.

ATKINS, W. R. G.—Notes from the Botanical School of Trinity College, Dublin, III, p. 133 (1922).

JAMIESON, T. F.—Reports of the Agricultural Research Association. Aberdeen (1892).

POTTS, G.—Report of the British Association, South Africa, p. 596 (1905).

RECORDS OF FUNGI IMPERFECTI.

With 4 Text-figures.

By Jessie S. Bayliss Elliott, D.Sc. and Olive P. Stansfield, M.Sc.

During 1920 and 1921, in the course of collecting material for another investigation, we have met with the following fungi, of which *Septocylindrium leucum, S. melleum, Patellina caesia, P. diaphana* are new species; *Lemalis aurea, Hadrotrichum virescens* var. *Poae, Penicillium silvaticum* are new records for the British Isles, and *Oospora ochracea, Tetraploa aristata* and *Sporodesmium myrianum* seem worthy of note.

SEPTOCYLINDRIUM LEUCUM n.sp.*†

The mycelium forms gregarious superficial white brittle tufts on the surface of pine cones. The hyphae are very short so that the entire tuft is a mass of conidia. These are produced basipetally in repeatedly branched chains and are cylindrical in shape with truncate ends; they measure 10–15 × 1·5–2 μ, are from one to three septate and are produced in great quantities. They are rough, being covered with minute granules which soon disappear in water. The conidia germinate easily in rain water in the course of 24 hours.

This fungus agrees in many details with *Septocylindrium album* (Preuss) Sacc., recorded (without size of spores) by Preuss (in Sturm, Deutsch. Fl. III, 29 and 30 (1851), pp. 73, t. 37) as growing on decaying stumps of wood near Hoyerswerda in Germany, but it is evidently not the same fungus for the conidia are described and figured as definitely spindle-shaped,

* *Septocylindrium leucum* n.sp.

Hyphis conidiophoris brevissimis, in fasciculos gregarios, superficiales, albos, fragilissimos digestis. Conidiis copiosis, cylindricis, truncatis, 1–3 septatis, 10–15 × 1·5–2 μ catenas repetite ramosas efformantibus.

Hab. in conis *Pini sylvestris* herba semisepultis toto anno, Tanworth-in-Arden.

† Found also on pine cones sent by Dr C. E. Fairman from Lyndonville, N.Y.

thus contrasting with the cylindrical conidia with truncate ends typical of this fungus.

The fungus is to be found growing on cones of *Pinus sylvestris*, half buried in grass at Tanworth-in-Arden, near Birmingham, all the year round.

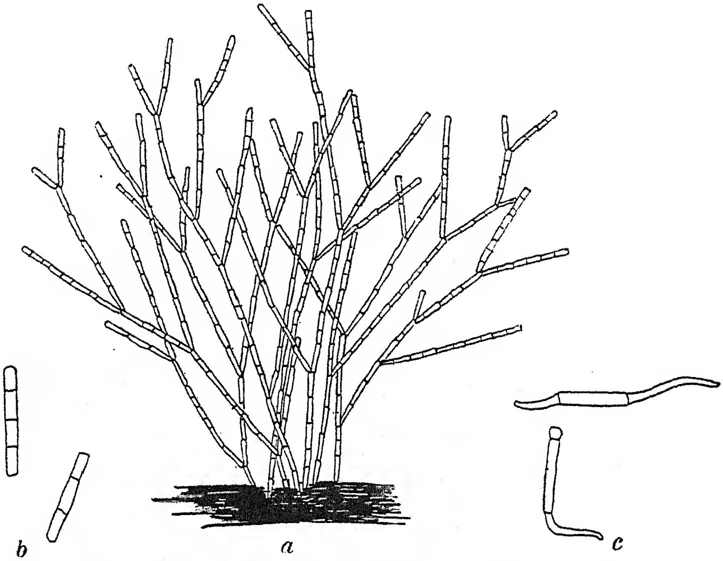

Fig. 1. *Septocylindrium leucum*. (*a*) Sporophore. × 750. (*b*) Conidia. × 1600. (*c*) Conidia germinating. × 1600.

SEPTOCYLINDRIUM MELLEUM n.sp.*

Another fungus similar in nearly all details, except colour, to *S. leucum* was found on the same cones of *Pinus sylvestris* at Tanworth-in-Arden. The appearance of the fungus suggests that it is a buff variety of *Septocylindrium leucum*, but the absence of 3-septate conidia and also of granules makes it advisable to describe it as a separate species.

PATELLINA CAESIA n.sp.†

This fungus was found growing on cones of *Pinus sylvestris*

* *Septocylindrium melleum* n.sp.

S. leuco, praeter colorem, simillimum, at calore melleo, conidiis 1 septatis, species diversa videtur.

Hab. in conis *Pini sylvestris*, Tanworth-in-Arden.

† *Patellina caesia* n.sp.

Excipulum patelliforme, apothecio Discomycetis simile, griseum, pubescens, circa 1 mm. latum.

Hyphis conidiophoris fasciculatis, ramosis, cylindricis, apice in catenas longas sporarum abeuntibus; conidiis hyalinis cylindricis, utrinque oblique truncatis, ca. 10 × 1·5μ.

Hab. in conis *Pini sylvestris*, Tanworth-in-Arden, prope Birmingham.

at Tanworth-in-Arden. Its saucer-shaped form gives it very much the appearance of a Discomycete, but the disc is surmounted by a grey mucilaginous column or dome consisting of innumerable conidia which are washed off by rain and lie around as a grey mucus. The excipulum is composed of pure white hairs arranged parallel to one another, some slightly radiating outwards; when shut up in a very moist atmosphere the hairs stand out almost like those of a Dasyscypha. The

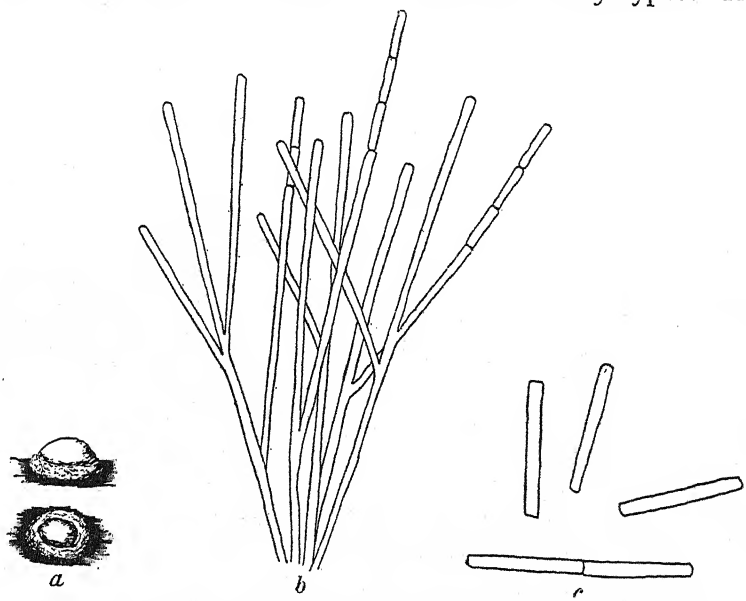

Fig. 2. *Patellina caesia.* (*a*) Pycnidium with dome of spores. × 15. (*b*) Hymenial surface. × 1000. (*c*) Spores. × 2400.

interior of the saucer is lined with a grey hymenial surface, composed of fascicles of branched conidiophores each producing at its apex a long chain of hyaline cylindrical spores, obliquely truncate at both ends, and measuring 10 × 1·5 μ.

The fungus evidently belongs to the Excipulaceae division of the Sphaeropsideae, and it is highly probable that it is the conidial stage of some Discomycete.

PATELLINA DIAPHANA n.sp.*

This fungus was found growing on a dead root of poplar at Tanworth-in-Arden. It has the same form as *P. caesia* and is

* *Patellina diaphana* n.sp.

P. caesiae simillima, sed glabra et tota alba. Conidiis similibus, non longe catenatis, 5–6·5 × 1–1·5 μ hyphis longioribus suffultis.

Hab. in radicibus *Populi*, Tanworth-in-Arden. Status conidiophorus Discomycetis.

evidently closely allied to it, but is white in colour. The column of conidia surmounting the disc, as in the above species, is mucilaginous and white. The excipulum having a saucer-shaped form is composed of very narrow parallel hyphae. The interior is lined with branched conidiophores, the branches arising in whorls, near the base. The conidia arise laterally on the conidiophores and do not cling together in chains.

The conidia measuring 5–6·5 × 1–1·5 μ are cylindrical in shape and truncate at both ends. This fungus differs from *P. caesia* in the absence of hairs on the excipulum; in the size and method of growth of the conidia and conidiophores, the conidia being

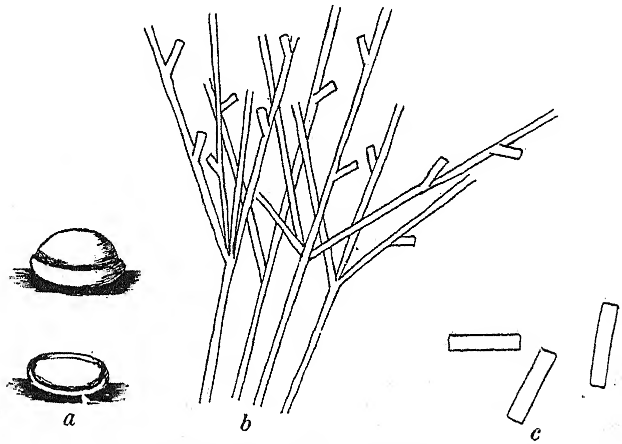

Fig. 3. *Patellina diaphana.* (*a*) Pycnidia. × 20. (*b*) Conidiophores. × 1500. (*c*) Spores. × 2250.

smaller and the conidiophores much longer; also in colour. It is highly probable that this also is the conidial stage of some Discomycete.

Lemalis aurea (Lév.) Sacc. Syll. Fung. III, p. 672 (1884).

Excipulum lemon yellow, cup shaped with a spreading rim, exterior shining, very fragile, 1 × 1 mm. The rim of the cup is marked by hairs which cling together in groups giving it a coarsely dentate appearance. A hymenium of conidiophores lines the pycnidium which is composed of very slender non-septate hyphae ·75 μ wide, each conidiophore consisting of an aseptate hypha with a whorl of four branches at the apex.

The pycnospores are globose, hyaline, 1·5–2 μ diam. and are produced basipetally in chains in enormous quantities. The spores cling together by means of mucus and are exuded from the cup in the form of a straight or tortuous column; a column may be three or four times the volume of the cavity of the

pycnidium. Finally the column of pycnospores topples over and in drops of water the spores quickly disperse.

Very young excipula are extremely shallow in form, some, when measuring 160 μ in diameter and being only 60 μ in height, were producing a great profusion of conidia. The fungus was found on cones of *Pinus sylvestris* at Tanworth-in-Arden.

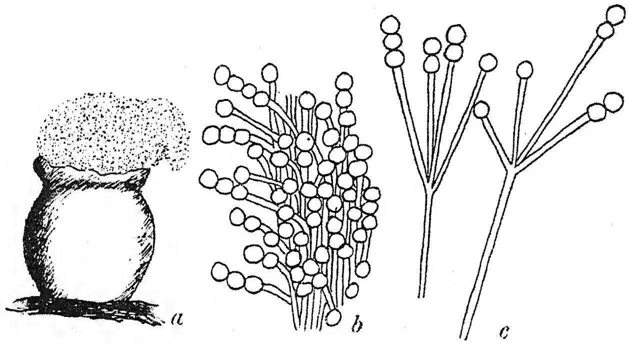

Fig. 4. *Lemalis aurea* Lév. (*a*) Pycnidium with pycnospores. × 15. (*b*) Hymenial surface. × 1000. (*c*) Conidiophores with spores. × 1500.

Hadrotrichum virescens Sacc. and Roum. var. *Poae* Sacc. in Ann. Mycol. II (1904), p. 529.

This fungus, considered by Saccardo to be the conidial stage of *Phyllachora Poae* (Fuck.) Sacc., was found growing on *Poa pratensis* at Tanworth-in-Arden. It forms black cindery stromata on the leaves. These are at first punctiform but soon coalesce to form black patches: the tissue of the leaf round the stroma turns yellow and finally the whole leaf dies.

The dark brown simple clavate conidiophores arise from the stroma in fascicles and finally burst through the epidermis. At the apex of each conidiophore a single globose conidium is produced, measuring 10–12 μ diameter.

Penicillium silvaticum Oud. in Arch. Néerl. Sci., Ser. 2, VII (1902), p. 289.

This fungus was first recorded by Oudemans for Holland and later by Jensen (Cornell Univ. Agric. Exp. Stat. Bull. No. 315 (1912)) for America. It is interesting to note that the specimen was growing in a Petri-dish culture of agar, a situation very similar to that recorded by Oudemans. Jensen had found it amongst the soil fungi which he had isolated and it is very probable that the specimen found in the Botany Laboratory of Birmingham University was a result of an infection from soil brought into the department.

The mycelium which was pale sepia brown consisted of sterile branched septate hyphae from 3–6 μ thick, and erect fertile

hyphae up to 210 μ high. These branched penicillately, forming a head of flask shaped branches which produced very long chains of globose, smooth, hyaline conidia which were slightly tinted brown and measured 3 μ diameter. In the specimen examined by Jensen the mycelium formed non-zonate patches; our specimen, however, showed slight zonation.

RARE FUNGI.

During 1921 we met with the following rare fungi:

Oospora ochracea (Corda) Sacc. and Roum. Forming gregarious pinkish-grey velvety tufts on apricot jam.

Tetraploa aristata B. and Br. On grass (probably *Poa pratensis*) cut and thrown into a heap; also on living roots of grass.

Sporodesmium myrianum Desm. On *Psamma arenaria* Borth, North Wales and Sandwich, Kent.

In conclusion we thank Mr W. B. Grove for valuable help in the identification of some of the above species.

REVIEW.

British Basidiomycetae, a Handbook of the larger British Fungi, by CARLETON REA. Pp. xii + 799. £1. 10*s*. net. Cambridge University Press. 1922.

The publication of this important work, embodying the accumulated knowledge of thirty years' work in the field, has been awaited by members of the British Mycological Society with a peculiar interest.

It is well known how Mr Rea acted as Secretary to the Society for many years, practically managed the Forays singlehanded, and was responsible for the naming and listing of the huge quantities of material collected. The beautiful coloured plates, painted by Mrs Rea, were invaluable for placing on permanent record rare or new species.

The work has been delayed by printing and publishing difficulties arising from the War. The author is to be congratulated on the success of his great effort.

The Handbook will be welcomed not only by all Mycologists in this country, but also by Continental botanists, and will be assigned a worthy place among the most esteemed Fungus Floras of France, Sweden or Germany.

An appreciation of its merits can only be arrived at after a prolonged study of its contents, and considerable experience in comparing the groupings and descriptions with the Fungi themselves, but even a limited practical acquaintance with it is sufficient to demonstrate its value. The time and labour required in its compilation must have been great.

Mr Rea deals in this volume with the Basidiomycetes alone—a sufficiently large field!

His classification differs from that of Fries, to which we have been so long accustomed, and which in this country has hitherto practically held the field. Its distinctive features need not be set down here. They are clearly stated in the Introduction and in the elaborate Key to the Divisions and Genera. The system of classification is based on that of Patouillard with alterations and additions by other eminent Continental mycologists, and even an hour's study of it will render it intelligible to any one possessed of the necessary preliminary knowledge. It is ingenious, comprehensive and scientific, but whether it deserves to supersede, for practical purposes at any rate, the simpler classification of Fries is open to question.

Amateur field botanists who have learnt the Agarics on the Friesian system will not regard the new arrangement with kindly feelings, as the order of the genera is so confused that one cannot turn up well-known species without continual reference to the index. The modern school of mycologists, however, who aim at determining Agarics by microscopical features, will welcome it. The older men will demur, and the younger men may applaud.

It is to be remembered that the work is a Handbook to the larger fungi, and the less elaborate classification may be regarded as the more appropriate. However that may be, the classification followed in the present work is an interesting departure from the timeworn tradition of mycologists in this country, and deserves an opportunity of fighting its way into general favour. If, after a period of testing, it turns out to be practically superior to that of Fries and Berkeley, it will be welcomed and adopted; if not, it will still be valuable as an able and consistent attempt to arrange the great mass of material dealt with, on a fresh basis. After all, the main features of the Friesian System are still preserved.

It might have been well if in the preliminary Key, to which one naturally looks for guidance, the page where each group was to be found had been set down in consecutive order. This however is a small matter as the Index is all that could be desired, complete and well arranged, so that any single species or group of fungi can at once be found without any difficulty.

The descriptions are excellent, based of course on those of Fries, but with additional features often added, drawn either from long observation on the part of the author, or culled from the works of Continental mycologists. By the judicious use of italics, attention is drawn to the main points of distinction between neighbouring species. Measurements of spores are given for most species, and in the case of a considerable number, those of cystidia also. The former could not well have been omitted, although being variable, much stress cannot be laid on them.

As regards the measurements and shapes of cystidia it is very doubtful whether they ought to have been included at all. Their part in the life-history of a fungus is unknown, and it seems unwise and unnecessary to allow them to enter into the determination of species of Basidiomycetes, which, if they are true species at all, have a sufficient number of obvious features to separate them from one another. To study such organs is interesting and scientific, but to give them a place in the description of a species is quite a different thing.

What some will miss in these descriptions are even the briefest notes regarding the localities of the rarer species, and any hints of a popular kind as to points that might help to separate one fungus from another. No one could have supplied these better than Mr Rea, but probably he was influenced by consideration of space.

One great merit of the volume is the inclusion, up-to-date, of all species recently introduced into our British fungus-flora. These can now be recognised at once when they are met with, and the trouble of tracing them through the pages of scattered publications is avoided.

A tendency has been observed, especially in later years, to multiply species unnecessarily by laying undue stress on comparatively trivial points of difference. Neither Fries nor Berkeley nor Quélet was guilty of this error nor is Mr Rea much to blame, but many will desire that he had not had so much consideration towards these species but rather dealt with them with a master hand, so striking at the root of an evil which has been flourishing too long. Examples will occur to any experienced mycologist. We shall soon be overweighted by "species" which are not independent species, but mere varieties of others, and which add confusion to the difficulties of identification which are already so formidable.

A word may be added as to the title of the book. No doubt Mr Rea felt himself bound to follow the rules laid down by Saccardo and approved by the British Mycological Society at their Meeting at Whitby in 1904 but, *pace* Saccardo, the word BASIDIOMYCETAE is an impossible word, neither Greek, Latin nor English; it should have been BASIDIOMYCETES. Saccardo was no doubt a good mycologist, but he was a bad grammarian.

There will of course be differences of opinion as to different features in a voluminous work of this kind, but all mycologists will agree in recognising its great merit, and in giving it a hearty welcome. It is indispensable to every student of the larger fungi. The better it is known the more it will be appreciated.

It is an honour to the British Mycological Society that it has appeared under its auspices.

W. B. ALLEN

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101. Fry, Miss E. J., University College of Wales, Aberystwyth. (1923.)
102. Fry, Miss P., B.Sc., A.R.C.S., Botanical Laboratories, The University, Liverpool. (1922.)
103. Gadd, Mr C. H., B.Sc., Royal Botanic Gardens, Peradeniya, Ceylon. (1921.)
104. Gardner, Capt. Frederic, c/o Lloyd's Bank, Jersey, C.I. (1898.)
105. Garside, Mr S., M.Sc., F.L.S., Botanical Department, Bedford College, Regent's Park, London, N.W. 1. (1922.)
106. Gates, Professor R. R., B.Sc., Ph.D., F.L.S., King's College, London, W.C. 2 (1921.)

107. Gilchrist, Miss Grace G., B.Sc., Botanical Department, The University, Bristol. (1921.)
108. Gilbert, Dr E. M., Botanical Department, University of Wisconsin, Madison, Wis., U.S.A. (1922.)
109. Goaman, Mr J. F., Hamble, St James' Road, Hereford. (1922.)
110. Gough, Mr G. C., B.Sc., A.R.C.S., Ministry of Agriculture, Birmingham. (1923.)
111. Gould, Mr F. G., Elmhurst, Church Hill, Loughton, Essex. (1918.)
112. Gould, Mr N. G., Royal Horticultural Soc. Gardens, Wisley, Ripley, Surrey. (1922.)
113. Green, Col. C. Theodore, A.M.S., M.R.C.S. L.R.C.P. F.L.S., 31, Shrewsbury Road, Birkenhead. (1901.)
114. Green, Mr E. Ernest, F.Z.S., F.E.S., Way's End, Camberley, Surrey. (1917.)
115. Grinling, Mr C. H., B.A., 71, Rectory Place, Woolwich, S.E. 18. (1913.)
116. Gwynne-Vaughan, Professor Dame Helen, D.Sc., LL.D., F.L.S., 93, Bedford Court Mansions, London, W.C. 1. (1906.)
117. Haas, Mr P., D.Sc., Ph.D., F.C.S., University College, Gower Street, London, W.C. 1. (1921.)
118. Hadden, Mr Norman G., Underway, West Porlock, Somerset. (1911.)
119. Hake, Miss Winifrede L., 28, Lillie Road, London, S.W. 6. (1922.)
120. Hansford, Mr C. G., B.A., Microbiologist, Department of Agriculture, Jamaica. (1921.)
121. Harvey, Mrs Cecily D., Barwick in Elmet Rectory, nr. Leeds. (1910.)
122. Hasluck, Miss I. E., Green Hill Park, New Barnet, Herts. (1922.)
123. Hastings, Mr Somerville, M.S., F.R.C.S., 43, Devonshire Street, Portland Place, London, W. 1. (1913.)
124. Hawley, Sir H. C., Bart., The Manor House, Lytchett Matravers, Poole, Dorset. (1907.)
125. Hildyard, Mr F. W., 14, Lambridge, Bath. (1913.)
126. Hiley, Mr Wilfred E., M.A., F.L.S., Research Institute, School of Forestry, Oxford. (1913.)
127. Hoare, Mr A. H., 111, Blenheim Gardens, Wallington, Surrey. (1922.)
128. Holt, Mr W. H., 17, Ashville Road, Birkenhead. (1914.)
129. Honolulu, The Library, Experiment Station, S.P.A., Box 411 Hawaii. (1920.)

130. Horne, Mr A. S., D.Sc., F.L.S., F.G.S., Botanical Department, Imperial College of Science, South Kensington, London, S.W. 7. (1921.)
131. Howard, Mr H. J., F.R.M.S., "Lingfield," 6, College Road, Norwich. (1918.)
132. Hughes, Mr G. C., Chesterton, Bicester, Oxon. (1898.)
133. Humphrey, Mr C. J., Laboratory of Forest Pathology, Old Soils Building, University of Wisconsin, Madison, Wis., U.S.A. (1921.)
134. Hunter, Mr C., M.Sc., Botanical Department, The University, Bristol. (1921.)
135. Hurrell, Mr H. E., 25, Regent Street, Great Yarmouth. (1921.)
136. Illinois, The Library, University of, Urbana, Illinois, U.S.A. (1920.)
137. Issatchenko, Professor B. L., Directeur du Jardin Botanique, Petrograd, Russia. (1923.)
138. Jaczewski, Professor Arthur de, Director, Institute of Mycology and Phytopathology, Perspective Anglaise, 29, Petrograd, Russia. (1922.)
139. Johnson, Mr J. W. Haigh, M.Sc., F.I.C., F.L.S., Walton, nr. Wakefield. (1919.)
140. Johnstone, Mr R. B., 134, Cambridge Drive, Glasgow. (1908.)
141. Jones, Mr G. H., B.A., Botanical Department, Imperial College of Science, South Kensington, London, S.W. 7. (1922.)
142. Jones, Mr Robert Fowler, Austral House, Woodhall Spa, Lincolnshire. (1918.)
143. Jørstad, Mr Ivar, Statsmykolog, Botanisk Museum, Christiania, Norway. (1923.)
144. Keef, Miss Phoebe, Mortimer Lodge, Wimbledon Park, London, S.W. 17. (1921.)
145. Keilin, Dr D., Molteno Institute of Parasitology, Cambridge. (1922.)
146. Kelly, Dr Howard A., 1418, Eutaw Place, Baltimore, Md., U.S.A. (1921.)
147. Kendall, Miss O., Ministry of Agriculture, Pathological Laboratory, Milton Road, Harpenden, Herts. (1921.)
148. Kew, The Library, Royal Botanic Gardens. (1921.)
149. Kidd, Mrs Franklin, The Botany School, Cambridge. (1919.)
150. Knight, Mr H. H., M.A., The Lodge, All Saints' Villas, Cheltenham. (1914.)
151. Krieger, Mr L. C. C., 2114, N. Calvert Street, Baltimore, Md., U.S.A. (1921.)
152. Kulkarni, Mr G. S., M.Ag., Assistant Professor of Mycology, Agricultural College, Poona, India. (1922.)

153. Leicester, The Museum, City of Leicester. (1923.)
154. Line, Mr James, M.A., School of Agriculture, Cambridge. (1921.)
155. Linnean Society, The, Burlington House, Piccadilly, London, W. 1. (1919.)
156. Lister, Miss Gulielma, F.L.S., 871, High Road, Leytonstone, Essex, and Highcliff, Lyme Regis. (1903.)
157. Lloyd, Mr C. G., The Lloyd Library and Museum, 224, West Court Street, Cincinnati, Ohio, U.S.A. (1907.)
158. Lowndes, Mr A. G., M.A., Marlborough College, Marlborough, Wilts. (1922.)
159. MacCallum, Mrs B. D., M.A., D.Sc., F.L.S., Royal Botanic Gardens, Edinburgh. (1921.)
160. Macfie, Mr John William Scott, M.A., D.Sc., 21a, Alfred Street, Liverpool. (1900.)
161. Mackenzie, Miss A. D., Ministry of Agriculture, 4, Whitehall Place, S.W. 1. (1921.)
162. Mackenzie, Mr D., Afton, Busby, N.B. (1900.)
163. Main, Mr Robert, 1, Roslyn Avenue, Low Fell, Gateshead. (1918.)
164. Maire, M. René, D.Sc., Professeur à la Faculté des Sciences de l'Université, Algers, Algeria. (1907.)
165. Maitland, Mr T. D., Government Botanist, Department of Agriculture, Kampala, Uganda. (1916.)
166. Maltby, Mr G. C., 14, Northwick Road, Evesham. (1923.)
167. Marmont, Mr Basil P., Windsoredge House, Inchbrook, nr. Woodchester, Gloucestershire. (1908.)
168. Marriott, Mr St John, 37, Owenite Street, Abbey Wood, London, S.E. 2. (1920.)
169. Marshall, Mr A., 21, Potter's Hill, Aston, Birmingham. (1921.)
170. Mason, Mr E. W., M.A., M.Sc., Imperial Bureau of Mycology, 17, Kew Green, Kew, Surrey. (1921.)
171. Mason, Mrs E. W., 10, Manor Gardens, Richmond, Surrey. (1922.)
172. Mason, Mr F. A., F.R.M.S., M.S.P.A., The Laboratory, 3, Queen's Square, Leeds. (1912.)
173. Mason, Mr F. R., Assistant Mycologist, Department of Agriculture, Kuala Lumpur, Federated Malay States (1921.)
174. Matthews, Mr J. R., M.A., F.L.S., Royal Botanic Gardens, Edinburgh. (1921.)
175. McLean, Professor R. C., M.A., D.Sc., F.L.S., Botanical Department, University College, Cardiff. (1922.)
176. McCutcheon, Mr William, B.A., B.Sc., Goulburn, 89, Argyle Road, Saltcoats, N.B. (1920.)

177. McDougall, Professor W. B., University of Illinois, Urbana, Ill., U.S.A. (1921.)
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179. Melbourne, The Director, Department of Agriculture, Science Branch, 605, Flinders Street, Melbourne, Australia. (1921.)
180. Melvill, Mr J. Cosmo, M.A., D.Sc., F.L.S., Meole Brace Hall, Shrewsbury. (1922.)
181. Menzies, Mr James, 117, Scott Street, Perth. (1917.)
182. Meulenbroff, Dr J. S., President, Dutch Mycological Society, Zwolle, Holland. (1921.)
183. Missouri, The Botanical Garden, St Louis, Mo., U.S.A. (1902.)
184. Miyabe, Dr Kingo, Professor of Botany, Hokkaido Imperial University, Sapporo, Japan. (1919.)
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188. Mounce, Miss Irene, M.A., Botanical Department, University of Manitoba, Winnipeg, Canada. (1921.)
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210. Page, Miss W. M., B.Sc., Birkbeck College, Breams Buildings, Chancery Lane, London, E.C. 4. (1921.)
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248. Rothamsted Experimental Station, Department of Mycology, Harpenden, Herts. (1923.)

249. Rushton, Mr W., A.R.C.S., D.I.C., St Thomas's Hospital, Medical School, Albert Embankment, London, S.E. 1. (1914.)
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251. St Paul, Minn., U.S.A., The Library, Department of Agriculture, University Farm. (1920.)
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260. Searle, Mr G. Odell, B.Sc. (Agric.), Research Botanist, Linen Industry Research Association, Glenmore House, Lambeg, Lisburn, Ireland. (1920.)
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304. Wiltshire, Mr S. P., M.A., Imperial Bureau of Mycology, 17, Kew Green, Kew, Surrey. (1920.)
305. Wisconsin, The Library, University of, Madison, Wis., U.S.A. (1923.)
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307. Woolhope, The Naturalists' Field Club, Hereford, c/o Mr C. S. Scobie, 2, Offa Street, Hereford. (1896.)
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RULES.

Society's name and objects.

1. The Society shall be called "The British Mycological Society," and its object shall be the study of Mycology in all its branches.

Members of Society.

2. The Society shall consist of Honorary Members, Foundation Members and Ordinary Members; the number of Honorary Members shall be limited to 20, and that of Foundation Members to 100*, but the number of Ordinary Members shall be unlimited.

Honorary Members.

3. Honorary Members shall be persons of pre-eminence in Mycology, or who have rendered special service to the Society.

Foundation Members.

4. Foundation Members shall be those Members or Societies who joined the Society previous to the limit of 100 Members having been attained*.

Officers.

5. The Officers of the Society shall consist of a President, one or more Vice-Presidents, Treasurer, Secretaries, and Editor or Editors. They shall be elected annually at the Annual General Meeting of the Society.

Government of Society.

6. The government of the Society shall be vested in a Council, which shall consist of the President and other Officers for the time being, together with two or more other Members who shall be elected annually at the General Meeting, and one-half of whom shall retire each year and not be eligible for immediate re-election. The Members to retire shall be those who have been longest in office or, in case of equality, shall be determined by ballot. Ex-Presidents are *ex officio* Members of the Council.

Every Meeting of the Council shall be duly summoned by the Hon. Secretary by at least seven days' notice in writing to each Member of the Council.

* The limit of 100 Foundation Members was reached 22nd Oct., 1903.

Period of Office.

7. The Officers and Council shall hold office as from the 1st of January following their election.

Election of Members.

8. Honorary Members shall only be elected at a Meeting of the Society by a majority of the Members then present.

All Ordinary Members shall be proposed and seconded respectively by existing Members, who shall sign a certificate (see appendix) of recommendation, one at least of the proposers so certifying from personal knowledge. Every candidate for election shall sign an undertaking to abide by the Rules if elected (see appendix). They shall be elected by a majority of the Members present at any meeting of the Society or by the President and Officers of the Society.

Subscription.

9. All Ordinary Members and Societies shall pay an annual subscription of one pound, and Foundation Members five shillings, due on the 1st of January in each year. Honorary Members shall be exempt from any annual subscription.

Any Member wishing to retire from the Society shall give notice to the Hon. Secretary or Treasurer in writing before the 1st of December of the previous year.

Meetings.

10. The Society shall hold one or more Meetings annually, at a place and time determined by the Members at the preceding Annual General Meeting, or by the Council. The Annual General Meeting for the election of Officers and the transaction of other business shall coincide with the Autumn Foray.

Accounts.

11. At the Annual General Meeting of the Society in each year the Hon. Treasurer shall present duly audited accounts.

Alteration of Rules.

12. The Rules shall not be altered except by a two-thirds majority of the Members present at an Annual General Meeting. A printed copy shall be sent to every Member of the Society on election, and in the event of alteration to all Members.

APPENDIX.

Form of proposal for Ordinary Membership of the British Mycological Society.

....

of ....

....

being desirous of becoming an Ordinary Member of the British Mycological Society, we, the undersigned Members of the Society, certify that we consider h to be a desirable Member of the Society, and beg to recommend h for election.

Dated this day of 19

....(From personal knowledge).

Certificate to be signed by the Candidate.

I hereby certify that I desire to become an Ordinary Member of the British Mycological Society and that I will abide by the Rules if elected.

....

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